Lord Engrg.
Library

NOV 1 1937

The Welding Journal

THE JOURNAL OF THE AMERICAN WELDING SOCIETY PUBLISHED FOR THE ADVANCEMENT OF THE SCIENCE AND ART OF WELDING

VOLUME 16 SEPTEMBER 1937 NUMBER 9

Why USE A-C WELDING?

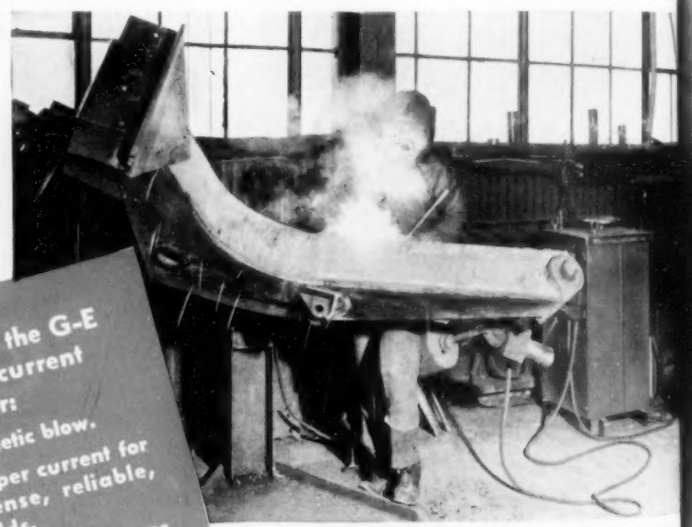
BECAUSE it's faster—on any application where magnetic blow slows up direct-current welding and limits the amount of current that can be successfully used. With G-E alternating-current equipment, trouble from magnetic blow is avoided—thus permitting heavier currents and larger electrodes to be used with the result that welding speeds are considerably increased. Here are some typical examples of a-c applications: thick-walled pressure vessels, high-pressure piping, penstocks, refining vessels, steam boilers, heavy machine frames, and similar applications.

Because it's better—on many heavy-current applications. Agitation of the molten pool of metal by the alternating current refines and improves the quality of the deposited metal. This characteristic, plus its avoidance of magnetic blow on heavy-current work, results in consistently stronger, denser, and more uniform welds than ordinarily obtained with direct current.

Perhaps there is a place in your plant where G-E alternating-current arc-welding equipment can be profitably used. Don't make costly compromises. Consult your local G-E arc-welding distributor or G-E sales office. They handle the largest variety of arc-welding equipment on the market, including a-c, d-c, and atomic-hydrogen equipment, in all sizes for hand or automatic operation. Their recommendations are unbiased and they have had years of experience in helping users to obtain maximum profits from their arc-welding applications. General Electric, Schenectady, N. Y.

G-E a-c transformer-type arc welder for such uses as repair, maintenance, and job-shop work. Welding range 50 to 150 amperes

G-E a-c transformer-type arc welder—sizes 300 to 1000 amperes



Large gooseneck arm, used to connect trailer to truck, being welded with G-E transformer-type welder

Advantages of the G-E Alternating-current Welder:

1. Avoids magnetic blow.
2. Provides proper current for making dense, reliable, uniform welds.
3. Saves up to 50% in power costs, as compared with rotating a-c welders.
4. Built with the care and workmanship that have characterized G-E transformers for 40 years.

GENERAL ELECTRIC

Dept. 6-201, General Electric Schenectady, N. Y.

Gentlemen:

Please tell me if G-E transformer-type welders could be profitably used on the type of work briefly described in the outline I have attached.

Name..... *Firm*.....

Street.....

City..... *State*.....

140-61

CHAIRMEN AND SECRETARIES OF SECTIONS

BIRMINGHAM
CHAIRMAN—E. E. MICHAELS, Chicago Bridge & Iron Co., P. O. Box 277
SECRETARY—J. E. DURSTINE, The Lincoln Electric Co., 505 N. 22nd St.

BOSTON—Engineering Societies of New England, 715 Tremont Temple
CHAIRMAN—P. J. HORGAN, General Electric Co., Lynn, Mass.
SECRETARY—P. N. RUGG, Edison Electric Illuminating Co. of Boston, 39 Boylston St.

CHICAGO
CHAIRMAN—TOM JONES, 8244 East End Avenue
SECRETARY—L. C. Monroe, The Welding Engineer, 608 S. Dearborn Street

CLEVELAND—Engineers' Rm. Carnegie Hall
CHAIRMAN—E. R. BENEDICT, Contract Welders, Inc., 2445 E. 79th Street
SECRETARY—E. T. SCOTT, The Cleveland School of Welding, Inc., 2261 East 14th Street

DETROIT
CHAIRMAN—J. D. TEBBEN, P. R. Mallory & Co., 2449 E. Grand Blvd.
SECRETARY—D. H. COREY, The Detroit Edison Co., 2000 Second Avenue

HAWAII
CHAIRMAN—E. E. HEACOCK, Hawaiian Gas Products, Ltd., P. O. Box 2454, Honolulu, T. H.
SECRETARY—R. L. MULLEN, Honolulu Iron Works Co., Honolulu, T. H.

KANSAS CITY, MO.
CHAIRMAN—C. E. WOODMAN, Kansas City Bridge Co., 215 Pershing Rd. Kansas City
SECRETARY—ALBERT W. ROTH, 1531 Broadway, Kansas City, Mo.

LOS ANGELES
CHAIRMAN—WAYNE A. HOWARD, General Petroleum Corp., 2525 East 37th Street
SECRETARY—RUSSELL L. GRAVES, (Res.) 3404 Sheffield Avenue, Los Angeles

MARYLAND—Baltimore Engineers' Club
CHAIRMAN—DR. J. W. MILLER, Reid Avery Company, Chesi & Cleveland Avenues, Dundalk, Md.
SECRETARY—C. N. HILBINGER, 1017 Walnut Avenue, Baltimore

MILWAUKEE
CHAIRMAN—K. L. HANSEN, Harnischfeger Corp., Milwaukee
SECRETARY—J. J. CHYLE, 2841 N. 51st Street, Milwaukee

MONTANA—Administration Building, Fort Peck
CHAIRMAN—HENRY F. C. RUMFELT, 701 Musselshell, Fort Peck
SECRETARY—ALLEN W. BATES, Apt. 4503 D, Fort Peck.

NEW YORK—33 West Thirty-Ninth St.
CHAIRMAN—R. W. BOGGS, The Linde Air Products Co., 205 East 42nd St., N. Y. C.
SECRETARY—MILTON MALE, United States Steel Corp., 71 Broadway

NORTHWEST—(Minneapolis)
CHAIRMAN—H. J. KICHERER, American Hoist & Derrick Co., St. Paul, Minn.
SECRETARY—ALEXIS CASWELL, Manufacturers Assn. of Minneapolis, 405 Marquette Avenue

NORTHERN NEW YORK
CHAIRMAN—W. F. HESS, Rensselaer Polytechnic Institute, Troy, N. Y.
SECRETARY—G. A. ROSS, General Electric Company, Schenectady, N. Y.

WESTERN NEW YORK
CHAIRMAN—H. J. SCHLEIDER, Air Reduction Sales Co., 730 Grant St., Buffalo, N. Y.
SECRETARY—F. O. HOWARD, American Steel & Wire Co., 1403 Liberty Bank Bldg., Buffalo

PHILADELPHIA—Engineers' Club, 1317 Spruce St.
CHAIRMAN—T. M. JACKSON, Sun Shipbldg. and D. D. Co., Chester, Pa.
SECRETARY—H. E. HOPKINS, Arcos, Inc., 401 N. Broad Street

PITTSBURGH
CHAIRMAN—E. J. W. EGGER, The Linde Air Products Co., 305 Ross St.
SECRETARY—J. F. MINNOTTE, Minnotte Bros. Co., 1201 House Building

PORTLAND
CHAIRMAN—G. C. DIERKING, Steel Tank & Pipe Company, P. O. Box 1899, Station F
SECRETARY—L. M. PICKETT, Steel Tank & Pipe Company, P. O. Box 1899, Station F

SAN FRANCISCO
CHAIRMAN—N. F. WARD, University of California, Berkeley
SECRETARY—J. G. BOLLINGER, Air Reduction Sales Co., Park Ave. & Halleck St., Emeryville

ST. LOUIS
CHAIRMAN—A. W. HARRIS, 2449 Milk Avenue, Alton, Ill.
SECRETARY—C. W. S. SAMMELMAN, 4359 Lindell Boulevard, St. Louis

YOUNGSTOWN, OHIO
CHAIRMAN—CHARLES WATSON, Youngstown Welding & Engr. Co.
SECRETARY—C. A. WILLS, Wm. B. Pollock Co., Youngstown, Ohio

THE AMERICAN WELDING SOCIETY JOURNAL

WM. SPRARAGEN, Editor
Published Monthly By The
AMERICAN WELDING SOCIETY

OFFICERS 1936-37

President, A. E. Gibson
Senior Vice-President, E. R. Fish
Treasurer, C. A. McCune
Secretary, M. M. Kelly
Managing Director, Warner S. Hays
Divisional Vice-Presidents
J. H. Zimmerman, New York & New England
R. D. Thomas, Middle Eastern
T. C. Smith, Pacific Coast
H. C. Boardman, Middle Western
E. E. Dillman, Southern Division

VOL. 16, NO. 9 SEPTEMBER 1937

CONTENTS

Technical Papers, Items and Reports Page

Good Practice in Structural Welding—A.R.E.A. Committee . . . 3
The New Lincoln Tunnel, by *Martin P. Korn* . . . 6
Welding of Stainless Steel, by *V. W. Whitmer* . . . 8
"Hand Operated Cutting Torches Retain Their Unlimited Application Scope," by *E. L. Mathy* . . . 19
Grand Coulee Dam, by *A. G. Wikoff* . . . 20
For the Auto Body "Doctor," by *E. R. Mecleary* . . . 23
Safe Ending Locomotive Boiler Flues and Super-Heater Tubes by the Electric Resistance Process, by *H. A. Woofter* . . . 24
Casing Pipe Welding, by *H. S. Card* . . . 27
Plate Crumples But Welds Hold, by *H. S. Card* . . . 28
Welded Ships, by *A. F. Davis* . . . 29
Repairing Casting, by *M. G. Mossholder* . . . 31
Jersey Municipal Stadium, by *H. C. Clark* . . . 31
New German Bridges, by *Dr. Ing. G. Schaper* . . . 32
World's Largest Rotary Lime Kiln, by *A. F. Davis* . . . 39
Some Factors to Be Considered in the Choice of a Welding Process, by *Louis J. Larson* . . . 40
Gargantuan "Tomato" Huge All-Welded Gasoline Storage Tank, by *R. B. Reid* 45
Building with Welding . . . 46
Current Welding Literature . . . 48
Index to Advertisers . . . 48

Society and Related Activities

A Message from Our President . . . 49
National Safety Council . . . 49
Larger Hard-Facing Booklet . . . 49
Introduction to Ferromagnetism . . . 49
Society Emblem . . . 49
July Welding Journal . . . 50
Steel Convention . . . 50
Pipe Lines . . . 50
Foundrymen's Convention . . . 50
Flame Hardening . . . 50
For Football Fans . . . 50
Lincoln Gold Medal . . . 50
Advantages of Steel Building Welding . . . 50
Structural Welding . . . 51
Lincoln Foundation, by *A. F. Davis* . . . 52
Obituary—*Major R. A. Bull* . . . 52
Employment Service Bulletin . . . 52
Section Activities . . . 52

Research Supplement

Translations . . . 1
Weld Failures! . . . 1
A Summary of Fatigue Strength of Welded Joints . . . 1
Preliminary Report of Subcommittee on Weld Stresses . . . 1
Report of Subcommittee of Non-Destructive Testing . . . 3
Resistance Welding Research Planned on Copper Alloys . . . 3
The Effect of Carbon and Manganese on the Weldability of Plain Carbon Steels . . . 3
Temperature Distribution During Welding—A Review of the Literature to January 1, 1937, by *W. Spraragen* and *G. E. Claussen* . . . 4
Fusion Welding Wrought Iron—A Review of the Literature to January 1, 1937, by *W. Spraragen* and *G. E. Claussen* . . . 11
The Effect of Total Carbon and Manganese on the Mechanical Properties and Structure of Welded Joints in Plain Low-Carbon Steel—A Review of the Literature to Jan. 1, 1937, by *W. Spraragen* and *G. E. Claussen* . . . 23

ISSUED MONTHLY

Copyright, 1937, by the American Welding Society

Subscription to those not eligible for membership $5.00 per year in United States and possessions; $5.50 in Canada and Foreign Countries. Single copies, non-members $1.00, members 50 cents.

Entered as second-class matter January 15, 1932, at the post-office at Easton, Pa., under the Act of March 3, 1879.

PUBLICATION OFFICE
20th & Northampton Streets, Easton, Pa.

EDITORIAL AND GENERAL OFFICES
33 West 39th St., New York, N. Y.

The Society is not responsible for any statement made or opinion expressed in its publications. Permission is given to reprint any article after its date of publication provided proper credit is given.

OXWELD* SHAPE-CUTTING MACHINES

Simplify Steel Fabrication

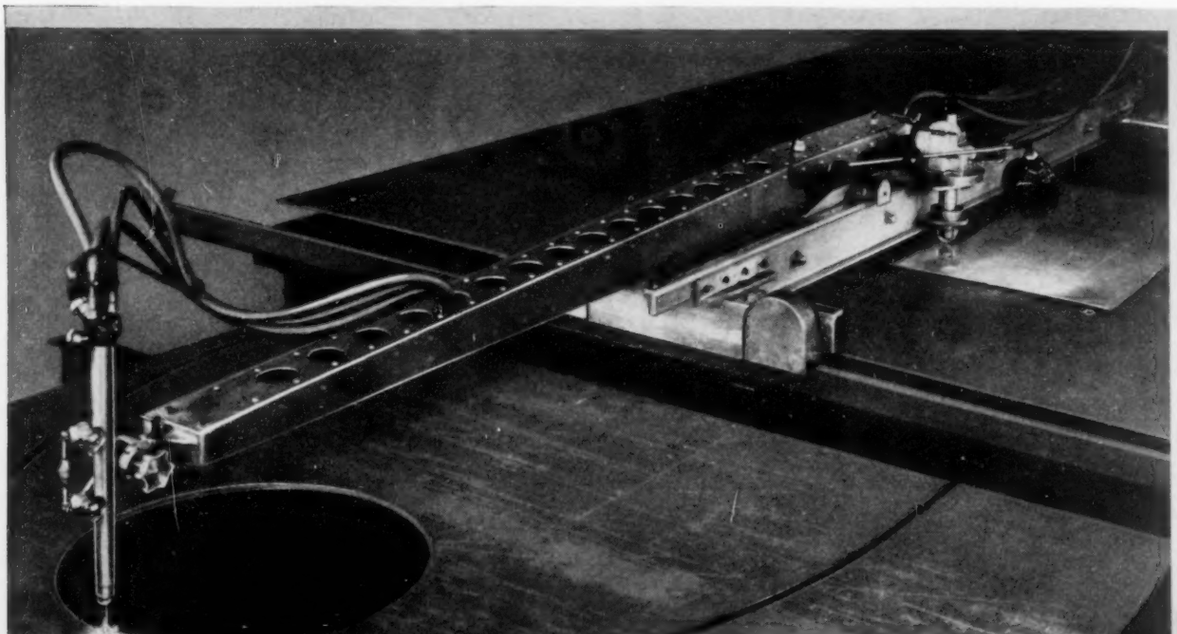
PRODUCTION can be simplified and speeded up in shaping steel parts by using oxy-acetylene flame cutting. Full advantage of this process can be obtained with new and improved stationary and portable Oxweld Shape-Cutting Machines.

Consider, for example, the stationary Oxweld CM-14. This machine has a transverse range of 100 inches—twice that of most oxy-acetylene machines. Its unusual capacity removes many of the problems encountered in fabricating metal products from exceptionally wide sheets. The CM-14 can also be used profitably for the ordinary run of smaller shop jobs.

Visit the Linde Exhibit
Booth H52
National Metal Show
Atlantic City, N. J.
October 18-22, 1937

A representative from the nearest Linde office will gladly assist your engineers in determining the economies that you can effect with flame cutting. He will help you select the portable or stationary Oxweld machine designed for your particular type of work. The Linde Air Products Company, Unit of Union Carbide and Carbon Corporation, New York and principal cities.

*Trade-Mark



You can utilize the full economies of flame cutting on metal of very large dimensions with the Oxweld CM-14 Shape-Cutting Machine.

Everything for Oxy-Acetylene Welding and Cutting

LINDE OXYGEN • PREST-O-LITE ACETYLENE • OXWELD APPARATUS AND SUPPLIES FROM UCC LINDE UNION CARBIDE

Arc Welding Field Splices on Large Steel Piling

Good Practice in Structural Welding

A.R.E.A. Committee Reviews Advantages and Limitations, and Shows Where and How It Can Be Applied in Repairing and Strengthening Existing Bridges and Other Types of Steel Work

BECAUSE of the advance in the knowledge and art of welding, particularly arc welding, the production of filler metal of a superior grade, and the development of fluxed electrodes, reliable welds may now be secured and definite results obtained by qualified welders working under careful procedure control. Gas welding has the advantage of requiring lighter, less expensive and more easily transported equipment than the arc process. It has the disadvantages of slower operation and of requiring the heating of a larger amount of the base metal. It should not be used for welding parts while under stress as there may be danger of permanent distortion. Arc welding should be used for work of considerable magnitude. It is usually done with direct current, but the use of alternating current is increasing because of its greater availability.

The new specifications of the AMERICAN WELDING SOCIETY limit the welding of structural steel to base metal with a maximum carbon content of 0.25 per cent. Steel with higher carbon content and various alloy steels may be welded, but the technique and the filler metal for some of them still are in the experimental stage. Cast steel, cast iron and wrought iron may be welded, a slightly different filler metal and method of operation being required for each. The strength of a wrought iron plate cannot be developed readily by a fillet weld because of the fibrous nature of the iron.

Filler metal may be of various compositions, the basis for acceptance being its physical properties and the properties of the resulting welds. At the present time there does not seem to be any reason for a specification for chemical composition, but for information and future use a record should be made of all the kinds of rods used, together with the location of their welds in the structure.

Filler metal is supplied in the form of wire rod, bare, washed or covered with various organic and mineral compositions. The object of the covering is twofold: (1) Shrouding the arc excludes air from the molten metal, and (2) a coating of slag is deposited on top of the bead. The first is of benefit in producing a denser and cleaner deposit; the second in prolonging the time of cooling, thus having a slight annealing effect. The washed rod deposits a slag but does not shroud the arc. Another effect of shrouding is to prevent dissipation of heat, thereby increasing the rate of deposition of the metal. Welds made with covered rods are stronger and more ductile than those made with bare rods but the danger of undercutting is greater.

Welds are of two types, butt welds and fillet welds. Butt welds resist deformation by direct tension or compression. Fillet welds resist deformation by shear. A fillet weld transverse to the line of stress resists partly by shear and partly by tension and therefore is stronger than an equal area of longitudinal fillet weld. The relation between resistance to shear and to tension is the same for filler metal as for base metal; hence a butt weld is stronger than an equal area of fillet weld. Tests show

* Abstracted by Railway Engineering & Maintenance, July 1937. A report presented as information by the Committee on Iron and Steel Structures before the convention of the American Railway Engineering Association on March 17, 1937.

that the ordinary ratio of tension to shear in metals applies also to welds.

Stresses

Welding as applied to steel structures is a comparatively new development, but enough tests have been made to establish the strength of welds under static loads. While studies of the effect of impact and of repeated and reversed loads have been made, more tests and studies are needed. The specifications of the AMERICAN WELDING SOCIETY determine the working units for welds by formulas developed from the results of endurance tests.

Due to the nature of the process of welding, small areas of base metal are heated to the fusion point and adjacent areas to a lower temperature. This heating causes expansion and the subsequent cooling causes shrinkage of the base and filler metals. The stresses resulting are sometimes of considerable magnitude. The effect of these locked-up stresses on the load-carrying capacity of the welded member has been investigated to some extent and some tests of full-size columns showed that the load-carrying capacity was not reduced. Much additional investigation in this field is needed.

Locked-up stresses can be reduced by certain stress-relieving procedures. Heat treatment is used in shop practice for some types of structures, but is generally not feasible for field welding. Peening the weld will relieve the stress in the weld to some extent but does not relieve the stress in the member. Locked-up stresses may be avoided to some extent if the parts are free to move during the process of welding. In this case the parts or the member as a whole may be distorted as a result of expansion and contraction. Distortion may be minimized by employing a sequence of welding procedure that will equalize the distribution of heat and also permit the parts to cool before the further application of heat.

Abrupt changes of section are points of concentrated stress. Change from one section to another should be gradual. The end of a weld should be tapered off, either by filling the crater or by planing.

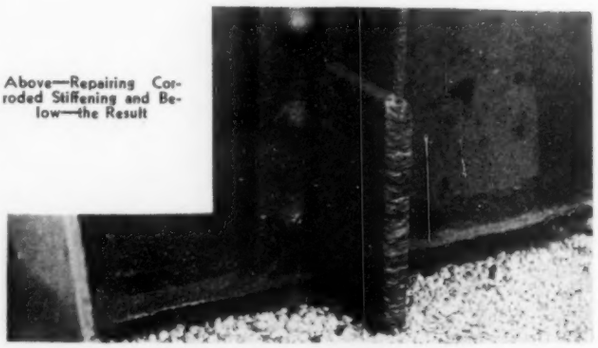
Any economy of welding over riveting usually results from the saving of material. Where the cost of material is high and that of labor low, the welded structure may be the cheaper. This applies particularly to new construction. In the repair or reinforcement of existing structures the case is somewhat different. The saving of material is important, but the advantage of working without interfering with traffic or taking the structure out of service, or even without removing parts, may overbalance any increased cost of material.

Joints should be designed especially for welding. Parts may be directly connected without connecting flanges and splice plates. The omission of rivet holes effects a saving of section. There may be situations where the use of gusset plates and connecting angles will serve to reduce the concentration of stress.

Left—Welding a Floor Grid to the Top Flanges of Floor Stringers

Qualification and Tests

The specifications of the AMERICAN WELDING SOCIETY prescribe tests for welders to be made both before and during the progress of the work. These tests are for the purpose of demonstrating the ability of the welder to make acceptable welds and to check any tendency toward carelessness as the work proceeds.



Above—Repairing Corroded Stiffening and Below—the Result

Tests of materials also are prescribed to show the weldability of the base metal and the suitability of the filler material. These tests should be made and the records kept for all work of magnitude or importance.

Inspection

Various methods of inspection have been developed, but the method most generally applied is visual inspection. Visual inspection requires men trained to know the qualities of welds and who are generally capable themselves of making good welds. It is important that there should be enough trained inspectors to cover the job and to keep the work of all the welders under practically continual observation.

There are a number of all-welded railway and highway bridges now in service in the United States, including railway bascule and highway swing bridges, but these embrace spans of moderate length. In building work welding has been used more extensively. However, by far the greatest use of welding as applied to railway bridges and structures, both in the United States and abroad, is for repairs and strengthening. Repair work usually involves some strengthening; the structure may be merely restored to its original strength, but it usually

happens that some material will be added so that the load-carrying capacity of the structure is increased. Some of the items of repair and strengthening may be noted briefly:

Cracks in flange angles are repaired by veeing and butt-welding. A short, triangular plate should be added at each end of the crack to prevent its extension.

A corroded stiffener angle may have its bearing area restored or increased by welding a plate to the outstanding leg or by flame-cutting away a portion of the corroded leg and butt-welding a plate in place of the removed portion. New stiffeners may be added. There may be flats instead of angles and need not be milled to fit the flanges. Bearing is best secured by welding a short plate across the outside edge of the stiffener and to the flange. A good stiffener is a "T" with the stem of the "T" fillet-welded to the web. If bearing is not required, the stiffener should be cut short.

Corroded lacing bars may be flame-cut from the member and new bars welded in place without removing the rivets.

New sole plates may replace old ones, and are attached by welding them to the edges of the flanges. The use of countersunk rivets will thereby be avoided. Water may be excluded from open holes by welding in a rivet punching. Holes should not be filled with weld metal because this will produce points of large stress concentration.

A broken or cut-back corroded anchor bolt may have a piece of rod welded to the end and a nut welded on the rod.

Reinforcing Cover Plates

Cover plates may be added to girder flanges to increase the section modulus of the girder. If there is no traffic interference, cover plates on the top flange should be successively narrower and those on the bottom flange successively wider to permit downhand welding. If traffic is to be maintained, it is usually cheaper to make the top cover plates of a deck girder wider and weld overhead. If the flange is wide it may be necessary to place slot welds between the fillet welds. If there are rivets in the flange, holes large enough to receive the rivet heads should be punched in the plate. If the plate requires an intermediate weld a fillet weld may be run around the perimeter of the hole and the balance of the hole containing the rivet head filled with plastic cement if it is so situated as to hold water. The abrupt change of section at the end of a plate is a point of concentrated stress, but this may be lessened by tapering the plate and ending it with a curve. Plates should be clamped tightly to the flange while the weld is being made and both edges should be welded simultaneously in short stretches.

Flange rivets, splice plate rivets and beam connection rivets may be reinforced by fillet welds along the edges of the plate or angle. Beam connections may be reinforced by adding shelf angles or brackets if clearance allows.

Girder webs may be reinforced by butt-welding plates between the flanges and fillet-welding them to the web. Special care is required in planning a sequence of welding that will minimize distortion. Slot welds may be required.

Protection of floor members against brine corrosion may be secured by tack-welding thin sheets over the tops of flanges and to the webs of floor beams.

Other Details

Gas-corroded overhead bracing may be repaired by cutting out the corroded parts and welding new sections in place. Corroded laterals and lateral plates may be replaced without cutting out flange rivets. Chord and web members may be reinforced by adding web plates or cover plates. Pairs of tension members may be made to resist compression by welding diaphragms between them or by connecting them by battens or lacing bars.

Worn pins may be wedged and welded. The bearing area may be increased by welding additional pin plates to the member. Loose eyebars may be cut and shortened. In this way two bars of a pair may be made to take equal stress. Elaborate methods for handling such problems have been developed by welding specialists.

Corroded rivet heads may be built up by welding, thereby avoiding the removal and redriving of the rivets. It should be recognized that this is not a means of reinforcing the rivet but only of preventing further reduction by corrosion. The clamping effect of a driven rivet cannot be restored by welding on a new head.

Building up imperfect castings and filling cavities in castings by welding is now an accepted practice. Broken machine parts may be repaired without dismantling the machine if the break is accessible. Worn and broken gear teeth may be restored. Broken gear teeth in the operating girder of a bascule bridge have been so repaired without interfering with the operation of the bridge. Where a large section of a tooth is broken out studs may be inserted, the weld metal built up around the studs and the tooth finished to exact section by grinding.

The welding of castings usually causes embrittlement. For that reason castings, if of considerable size and subject to stress, should be annealed after welding.

Advantages and Disadvantages

The foregoing examples give an idea of the great variety of repair and reinforcement work that may be accomplished by the application of fusion welding. In most cases not only is the actual cost less than for riveted work but the non-interference with traffic makes for convenience and economy. The time required usually is less, and in many cases riveted repairs would involve the removal of the member from the structure and its subsequent replacement, while welding avoids this.

Welding is desirable in residential and business districts, where the noise of riveting is objectionable.

In most cases it is not necessary to provide temporary supports for the track or structure, or to relieve the member of dead-load stress. Loading tests have shown by strain gage measurements that the added material takes its proportionate share of the live load. Below the yield point, strain is proportional to stress; therefore both old and new metal are equally stressed by the live load. However, there are situations where it may be advisable to relieve the member from stress while making the weld. Tests on small specimens have shown that under heavy direct tension or compression a large weld, particularly if at right angles to the line of stress, may weaken the member so that it will fail by stretching or buckling while hot. Fillet welds transverse to the line of stress may decrease the fatigue resistance.

At the temperature of fusion the metal is molten. The saving characteristic of electric arc fusion is that the area affected at one time is small and the effect continues for only a few seconds. Gas welding does not have these favorable characteristics and hence should not be used for welding members under stress.

Another feature that should be kept in mind is the difference in the ways riveted joints and welded joints act. A riveted joint functions partly by friction and slips slightly before the rivets come into full bearing. In a welded joint no such slipping can take place. The

welded joint is stiffer than the riveted joint and is, therefore, more affected by secondary stresses. Where a joint is partly riveted and partly welded this difference in manner of functioning should be taken into consideration. The specifications of the AMERICAN WELDING SOCIETY assume that all of the dead load is carried by the rivets and all of the live load by the weld. More experimental work is necessary to verify this.

Conclusion

It is apparent that the practice of welding is in advance of theory and somewhat ahead of exact knowledge. Welding offers a large field for research and experimental work, and a great deal is being done in all parts of the world. So much knowledge is now available that there need be no hesitation in applying welding in repairs and reinforcement. All-welded work should be adopted only after a thorough study, both technical and economic.

Consistent specifications should be adopted and rigidly enforced. Qualified operators and experienced inspectors should be employed. It is particularly necessary that the work be designed and the sequence of welding operations be outlined by a competent engineer who is experienced in fabricating welded steel structures.

The Specifications for Design, Construction and Repair of Highway and Railway Bridges by Fusion Welding of the AMERICAN WELDING SOCIETY for 1936, cover in detail the materials, equipment, processes, workmanship and inspection of gas and arc welding as applied to bridgework, new or old. These specifications may be obtained from the AMERICAN WELDING SOCIETY, 33 West 39th Street, New York City.

The New Lincoln Tunnel

By MARTIN P. KORN*

THE opening of the Holland Tunnel under the Hudson some years back was an event of national consequence. To engineers the world over it marked a singular achievement. To the folks around the country it spelled a new form of joy ride. Cars came from every state looking for that new wonder hole under the river. They found it, they got into line, down into the tubes they plunged!

And so it came to pass that all kinds of folk went to get thrilled and test their nerves, even welders. But when they went it was not as welders with helmets and goggles and all that—no, it was just as plain citizens in mufti, ordinary sightseers like John Smith and Mary Jane. For they had nothing to do with the building of that world's wonder in which structural strength was paramount. Welding was not used for strength, though it was probably good enough for repairing auto fenders and rat traps. That is the way the world was some ten years back, when welders knew their place and ate peanuts.

However, the earth does move and the times do change, and when the earth moves forward it is for better changes, and wherever there are better changes it is welding that makes them—you can ask any welder. Skyward with airplanes, upward with buildings and bridges, on earth in everything metallic that is industrial or utilitarian, downward with pipe lines, and now away down into the farthest depths underground the welders are at it with Gargantuan strength welding on tunnels destined to hold up the earth. And they were eating peanuts only ten years ago!

Under the Hudson River at 39th Street, New York, the new Lincoln Tunnel consisting of two vehicular tubes is now being constructed. Each tube has an outside diameter of 32 feet 10 inches in the rock tunnel sections and 31 feet in the shield driven tunnel. The outside lining is made up mostly of cast-iron segments and some cast-steel segments held together by several thousand tons of bolts of high tensile steel. Two designs were prepared for the rock tunnel sections on both the New York and the New Jersey sides, one design employing the standard cast-iron segment and an alternate design of built-up structural shapes shop welded into segments and field welded at all joints in addition to permanent field bolts. This alternate design was found more economical and it was finally adopted for all the land tunnel sections. Between portals the tunnel is about 8500 feet long. Welding is being employed in a length of about 1240 feet.

Shown here are typical details of these new shop-welded built-up segments. They are 60 inches wide. The cast-iron and cast-steel segments are 30 inches wide. A complete welded tunnel ring is made up of 11 built-up segments and a built-up key. The cast-iron and steel rings require 14 standard segments and a key. Right here one sees advantages resulting from a material reduction in the number of field splices and the number of pieces to be handled.

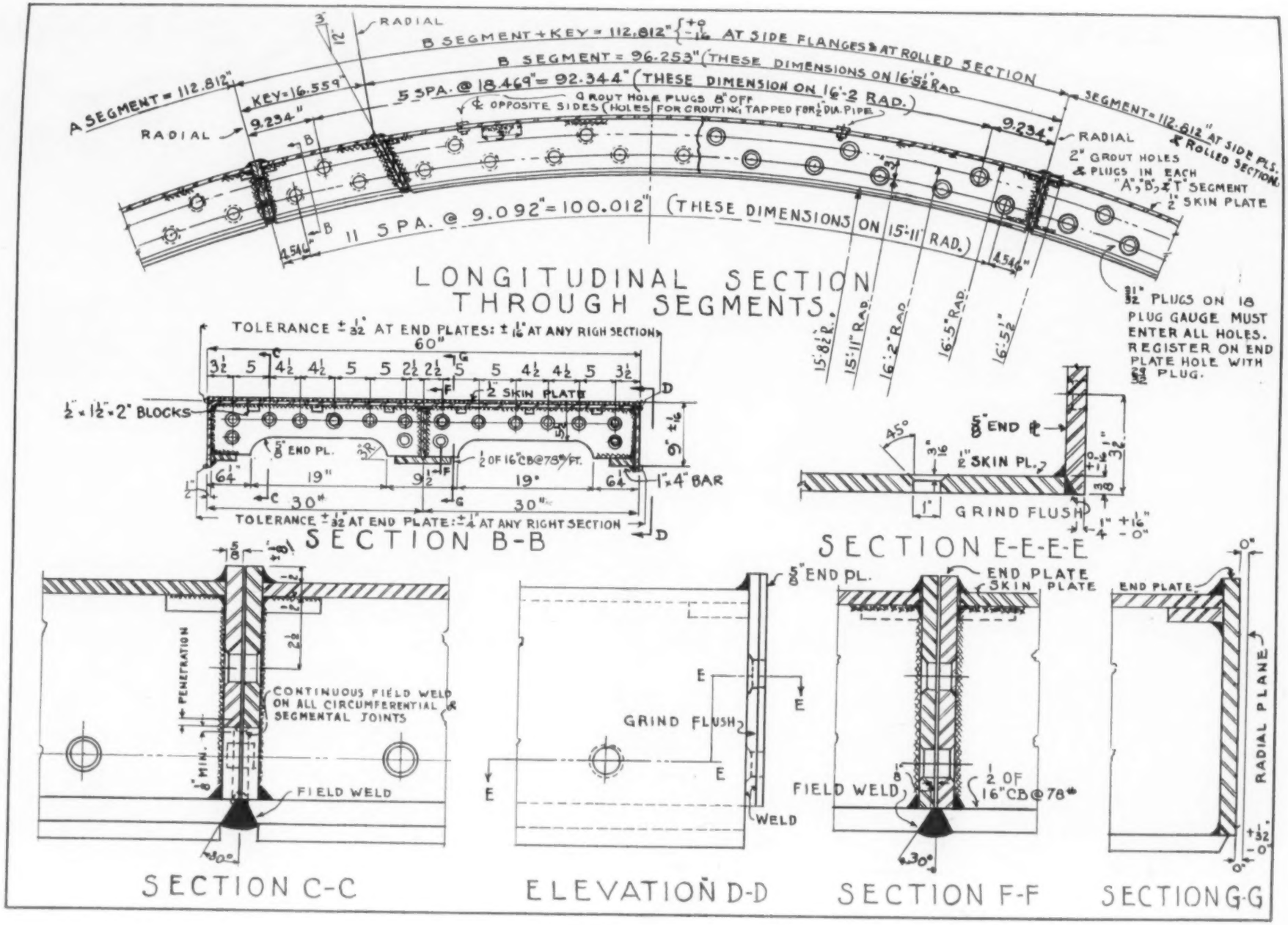
All welding is done by the shielded arc method. Shop welds are $^3/_8$ inch. There is a continuous field weld on all circumferential and segmental joints. Continuity in the circumferential ribs is obtained by the use of 1 inch V butt welds. The shapes used for the structural steel segments are of standard carbon steel. Note the minute tolerances allowed in those segments. That is what the engineers wanted and that is what they are getting. Plainly it is proof of how exact welded structural steel units can be fabricated today.

Look at the sketches, jot down savings in costs, note fewer pieces to be handled, fewer field splices and joints, a water-tight job, and you will know the whole story of why welded segments of structural shapes were selected in preference to the usual cast-iron segments for the rock tunnel sections. Add a footnote that those advantages resulted despite the continued use of carloads of permanent bolts! Then think what that augurs for the future of welding.

The Lincoln Tunnel was designed by the Port of New York Authority and its construction is being done under their direction, O. H. Ammann, Chief Engineer, Ralph Smillie, Engineer of Design, R. F. Schaefer, Asst. Engr. of Design.

The south tube having been started first will be opened for pleasure early in 1938.

* Consulting Engineer, Buffalo, N. Y.


A SEGMENT = 112.812"
B SEGMENT + KEY = 112.812" {+0 -1/16} AT SIDE FLANGES & AT ROLLED SECTION
B SEGMENT = 96.253" (THESE DIMENSIONS ON 16'-5½" RAD.
KEY = 16.559"
5 SPA. @ 18.469" = 92.344" (THESE DIMENSION ON 16'-2 RAD.)
GROUT HOLE PLUGS 8" OFF ℄ OPPOSITE SIDES (HOLES FOR GROUTING TAPPED FOR 1½ DIA. PIPE)
RADIAL
9.234"
4.546"
11 SPA. @ 9.092" = 100.012" (THESE DIMENSIONS ON 15'-11" RAD.)
SEGMENT = 112.812" AT SIDE PLS. & ROLLED SECTION
2" GROUT HOLES & PLUGS IN EACH "A", "B", & "T" SEGMENT
1½" SKIN PLATE
LONGITUDINAL SECTION THROUGH SEGMENTS.
15'-8½" R.
15'-11" RAD.
16'-2" RAD.
16'-5" RAD.
16'-5½"
31/32" PLUGS ON 18 PLUG GAUGE MUST ENTER ALL HOLES. REGISTER ON END PLATE HOLE WITH 63/32 PLUG.
TOLERANCE ± 1/32" AT END PLATES: ± 1/16" AT ANY RIGH SECTION
60"
1½" SKIN PLATE
½" × 1½" × 2" BLOCKS
⅝" END PL.
½ OF 16" CB @ 78" CTS.
1" × 4" BAR
30"
TOLERANCE ± 1/32" AT END PLATE: ± 1/4" AT ANY RIGHT SECTION
SECTION B-B
⅝" END ℄
45°
1" SKIN PL.
GRIND FLUSH
SECTION E-E-E-E
PENETRATION
CONTINUOUS FIELD WELD ON ALL CIRCUMFERENTIAL & SEGMENTAL JOINTS
FIELD WELD
30°
SECTION C-C
⅝" END PL.
GRIND FLUSH
WELD
ELEVATION D-D
END PLATE
SKIN PLATE
½ OF 16" CB @ 78"
SECTION F-F
END PLATE
RADIAL PLANE
SECTION G-G

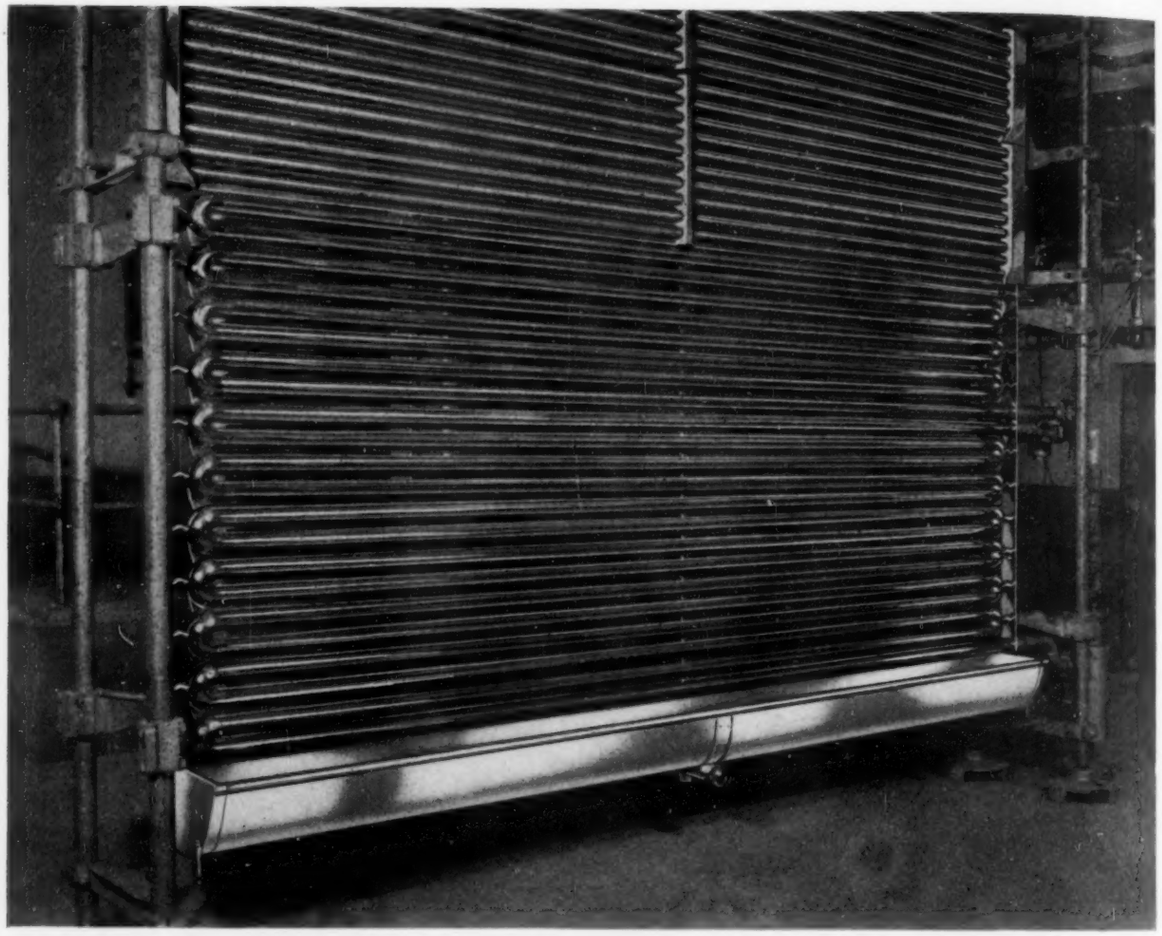


Fig. 1—Ammonia Sections of Ice Cream Mix Cooler in a Large Dairy Plant. The 22 Tubes at the Bottom Are Electrunite Enduro Stainless Steel Tubing, a Product of Steel & Tubes, Inc., Cleveland, Ohio. This Particular Shape Is Known as Drip-Lip or Keyway Tubing and Is Produced by a Patented Electric Resistance Welding Process. The Return Bends Are Flash-Welded

The Welding of Stainless Steel

By V. W. WHITMER*

DURING the last decade rapid strides have been made by the steel industry in the perfection of new alloys for the benefit of those industries demanding materials to withstand excessive heat and corrosion. These requirements have been met generally with the chromium and the chromium-nickel stainless steels. The degree of resistance to heat and corrosion is dependent upon the amount of alloying elements present.

The simplest of these alloys contains about 12% chromium. Various others contain this element in increasing amounts but the majority consist of iron alloyed with about 18% chromium and 8% or more of nickel, this last type falling in what is commonly called the austenitic class.

These stainless steels are highly resistant to acids such as nitric and to many others except sulphuric and hydrochloric. They are also resistant to oxidation and scaling at high temperatures and retain their physical properties well under heat. For these reasons they are being used more and more in the chemical, oil, dairy, food, paper and other industries requiring material with unusual corrosion and heat-resistance. They are supplied in plates, sheets, bars, strip, tubing, bolts, nuts, rivets, wire, etc., and can be rolled, drawn, formed or worked into almost any desired shape or apparatus merely by following the proper procedure for the individual product at hand.

In recent years welding has extensively replaced other forms of joining and its use is increasing steadily. This type of construction is readily adapted to the stainless steels, especially those containing 8% nickel or more.

As far as welding is concerned, practically the entire stainless steel field can be divided into two general classes: those containing only chromium as the alloying element, regardless of the amount; and the austenitic type, or those alloys containing both chromium and nickel in varying proportions.

The first class, ordinarily known as the straight

* Welding Engineer, Republic Steel Corp.

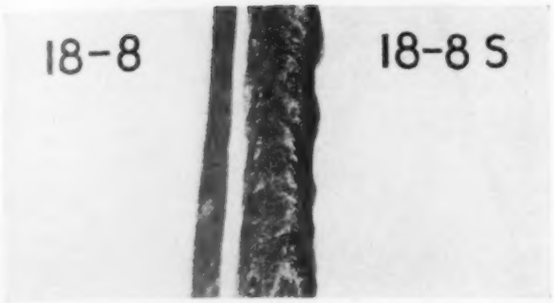


Fig. 2—Sections of 18-8 and 18-8-S as Welded and Subjected to Mixed Acid. Note Heavy Corrosion Parallel to Weld on 18-8 (Left) and Freedom from Attack on 18-8-S (Right)

Fig. 3—Same as Fig. 2, but Quenched from 1950° F. in Water After Welding. Note Freedom from Attack in Both Sheets

chromium stainless steels, especially those containing 18% or more chromium, when heated to a high temperature are subject to a rapid grain growth and do not respond satisfactorily to heat treatment.

They can be softened to a certain extent provided proper control is followed in welding by annealing for eight hours or so at about 1450° F. This may or may not be very satisfactory as much depends on the actual welding. As a rule numerous small beads will give the best results when followed by annealing.

Such alloys when welded possess very little ductility and therefore are not recommended where the product is subject to movement or shock at room temperature, as the welds are likely to crack on deformation or bending. However, if a little heat is applied or the operating temperature is about 200° F. or more, the welds will be much tougher and at 400 or 500° F. some bending will occur before breaking. Considerable thought should therefore be exercised before welding the straight chromium products.

The second class, or the chromium-nickel group, is most highly recommended for welding. These metals, being of an austenitic nature, are extremely tough and ductile in the as-welded condition. Where a straight chromium weld will probably snap as soon as bent, a chromium-nickel weld will bend back flat on itself with no sign of fracture.

These alloys, possessing properties as described above, can be satisfactorily welded as far as porosity or soundness is concerned by any commercial method in use today except forge or fire welding. On heating these alloys for fire welding, scale is formed on the surface. This scale, being insoluble, will not fuse properly with the commercial fluxes available at present. Hence, when pressure is applied, the two sections which are plastic but not molten at the ordinary welding heat are separated by this refractory scale or film which prohibits any adhesion between the two.

A list showing the approximate alloy content of a few of the Enduro Stainless Steels is shown in Table I.

The physical properties and welding characteristics of Enduro AA are fairly representative of all the alloys in the straight chromium group. Similarly, Enduro 18–8 is representative of the chromium-nickel types. Therefore, after a study of the welding properties of these two types, we can apply the same procedure with only minor changes, if any, to other alloys in these respective groups.

The 18–8 has a high thermal expansion of about 60% more than that of common steel, a low heat con-

Table I

Name	Carbon	Chromium	Nickel	
Enduro S-1	0.12 Max.	12.0–14.0%	.....	
Enduro S	0.12 Max.	14.0–16.0%	.....	
Enduro AA	0.12 Max.	16.0–18.0%	.....	
Enduro HC	0.35 Max.	23.0–30.0%	.....	
Enduro 18–8	Over 0.08 to 0.20 Max.	17.0–19.0%	7.0– 9.0%	
Enduro 18–8-S	0.08 Max.	17.0–19.0%	7.0– 9.0%	
Enduro 18–8-B	Over 0.08 to 0.20 Max.	17.0–19.0%	7.0– 9.0%	2.0–4.0% Silicon
Enduro 18–8-S-Ti	0.08 Max.	17.0–19.0%	7.0– 9.0%	4 times C. Titanium
Enduro 18–8-S-Mo	0.08 Max.	17.0–19.0%	7.0–11.0%	2.0–4.0% Molybdenum
Enduro 18–8-S-Cb	0.08 Max.	17.0–19.0%	7.0–12.0%	0.40% Min. Columbium
Enduro HCN	0.20 Max.	23.0–26.0%	11.0–14.0%	
Enduro NC3	0.25 Max.	24.0–26.0%	19.0–21.0%	

The average physical properties of Enduro AA and Enduro 18–8 are as follows:

	Enduro 18–8 (Annealed)	Enduro AA (Annealed)
Tensile strength	85,000 lb.-sq. in.	75,000 lb.-sq. in.
Elastic limit	40,000 lb.-sq. in.	50,000 lb.-sq. in.
Elongation in 2 inches	60.0%	25.0%
Reduction in Area	65.0%	60.0%
Hardness Brinell	140	160
Thermal Conductivity	40% that of mild steel	60% that of mild steel

Coefficient of Expansion	Enduro 18–8	Enduro AA
0–100° C.	16×10^{-6}	9.6×10^{-6}
0–300° C.	17×10^{-6}	10.1×10^{-6}
0–600° C.	18×10^{-6}	10.9×10^{-6}
0–1000° C.	20×10^{-6}	11.2×10^{-6}
Melting point	2560° F.	2650–2700° F.

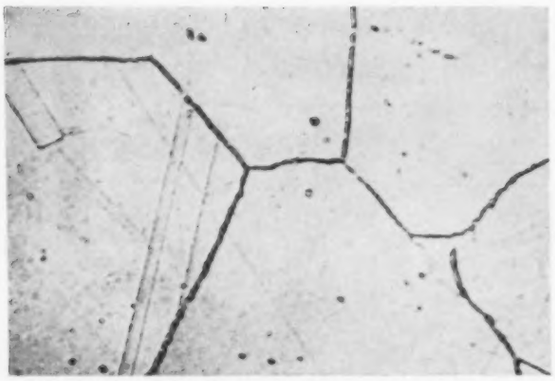


Fig. 4—Microsection Through Corroded Area of 18-8 as Welded in Fig. 2. Note Carbides in Grain Boundaries—×1000

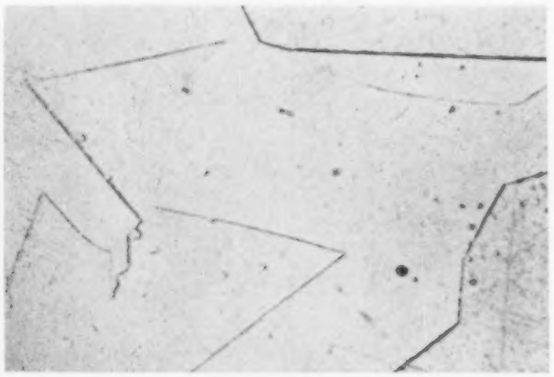


Fig. 5—Microsection Through Corresponding Area of 18-8-S in Fig. 2. Note Absence of Carbides (Sharp Narrow Grain Boundaries)—×1000

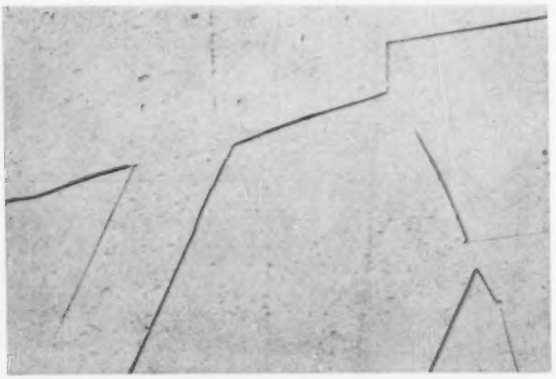


Fig. 6—Microsection Through Corresponding Area of 18-8 After Heat Treating as in Fig. 3. Note Absence of Carbides—×1000

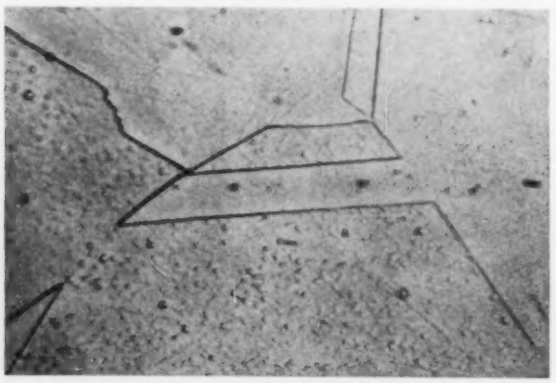


Fig. 7—Microsection Through Main Body of 18-8 Sheet in Fig. 2. Note Absence of Carbides in Original Stock Similar to 18-8-S After Welding

ductivity of about $1/3$ to $1/2$ that of common steel, and a lower melting point, in addition to being very fluid in the molten state. These same characteristics apply to the straight chromium type, except that the coefficient of expansion is about 10% less than that of common steel. These factors should be taken into consideration in the design of any welded equipment in order to prevent difficulties which might arise from undue strains, warpage, etc.

While alloys of the chromium-nickel group make by far the most satisfactory welds from the standpoint of physical tests, they do under certain conditions exhibit a tendency toward "weld decay." When an 18–8 stainless steel with more than 0.08% carbon is heated between 1000 and 1500° F., the excess carbon is precipitated or segregated out of solution and deposited along the grain boundaries in the form of carbides. These carbides are less resistant to corrosion than is the parent metal, with the result that wherever they are present more rapid attack will occur when exposed to corrosive conditions. In making a weld, the metal deposited and the joint itself are heated to the melting or fusing temperature, which is around 2690° F, the body of the work remains cold. Hence, there will be a zone parallel to and near the weld which will be heated between 1000 and 1500° F. and in which area carbides will be precipitated. This region may be wide or narrow, near or some distance from the weld, depending upon the type of joint and method of welding, which determines, of course, the total amount of heat applied. If welding is rapid, the zone will be narrow and close to the weld; if slow, it will be wide and further away.

This carbide can be put into solution again by heating to a temperature about 1900° F. or higher and cooling fast through the critical range. Air cooling will be sufficiently rapid if the section is thin, $1/16$-inch or less, but a water quench is advised if the apparatus is heavy.

If the material contains less than 0.08% carbon, such as Enduro 18–8-S, this carbide separation will be practically negligible, simply because there is not much carbon present and the small amount available remains in solid solution in the alloy itself. This carbide precipitation will not seriously affect the physical properties until it becomes quite extensive but it will reduce the corrosion resistance considerably if present even in small quantities. For this reason only 18–8-S is recommended for welded equipment which is to be subjected to highly corrosive attack and which cannot be conditioned after welding. It is also recommended for equipment operating at elevated temperatures, such as 1000° F. or higher.

While reducing the carbon content to below 0.07% will practically eliminate precipitation of carbides during the short time of welding, it will not necessarily stop such condition in equipment operating continuously between 1000 to 1500° F. Additions of such alloys as columbium, titanium, molybdenum, etc., to the low carbon product will still further reduce this tendency. Where heating alone is the factor, columbium or titanium is satisfactory. If corrosion-resistance is of most importance, then molybdenum is to be preferred.

This intergranular corrosion is characteristic of the chromium-nickel alloys of higher content as well as

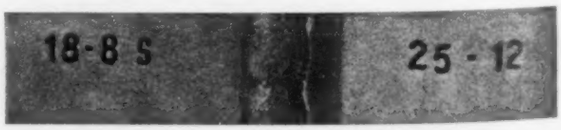


Fig. 8—Specimen of 25 Chromium—12 Nickel Welded to 18-8-S and Subjected to Mixed Acid. Note Same Corrosion on Higher Chromium and Nickel Alloy as on 18-8 in Fig. 2. High Chromium and Nickel Content Is Ineffective in Eliminating Weld Decay

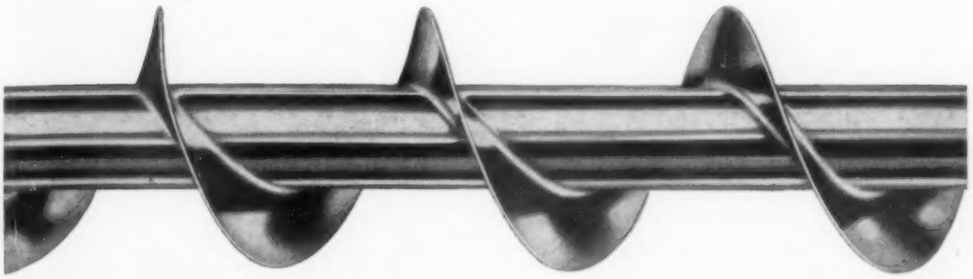


Fig. 9—Spiral Flange of Enduro Stainless Steel Arc Welded to Enduro Stainless Steel Tubing. Welds Are Ground and Polished. This Section Is Used as a Food Conveyor Worm

those containing only 18–8, provided the carbon is over 0.08%. This is shown very plainly in Fig. 8. An 18–8 low carbon is welded to a 25% chromium—12% nickel product containing higher carbon. Note the corrosion on the high alloy along the weld similar to that found in 18–8 with higher carbon.

Figure 2 shows a piece of 18–8 and 18–8-S welded together and subjected to acid attack in the as-welded condition. Figure 3 shows a similar sample exposed to the same acid but quenched from 1950° F. in water after welding. These illustrations show clearly the effect of high and low carbon on welding and the necessity of annealing when the carbon is high, if the equipment is to be subjected to highly corrosive conditions.

The photomicrographs shown in Figures 4, 5, 6 and 7 illustrate clearly the effect of high and low carbon and annealing on 18–8 material after welding.

While corrosion as indicated above will occur under highly corrosive conditions such as would be produced by an acid attack commonly found in the chemical industries, it should not be assumed that low carbons are essential for all welded equipment. Large quantities are consumed along other lines such as food handling apparatus, dairy equipment, architectural trim, heat-resisting units, etc., where the medium carbon contents have proved entirely satisfactory. Hence, unless the corrosion is unusually severe the regular 18–8 type will be found satisfactory.

Electric Arc Welding

Electric arc welding has been found to produce highly satisfactory results on stainless steels. Reverse polarity should be employed the same as when welding the non-ferrous metals, such as bronze, aluminum, copper, etc. That is, the wire or welding electrode is connected to the positive terminal of the generator, and the work to the negative. This is directly opposite the practice used with common steel bare wire, but quite similar to the practice followed with heavy flux coated rods of the shielded electrode type. While this will generally give best results, it cannot be made a hard and fast rule. Some instances have been found, especially when heavy plates were involved, where straight polarity produced better fusion and penetration. However, for light plates up to $^3/_{16}$ inch or so, reverse polarity is always advised.

Scarfing the edges is not necessary on anything up to $^1/_8$ inch in thickness. For $^3/_{16}$ inch, if only one bead is to be laid from one side, it is advisable to scarf the edges on a 45 degree angle to within $^1/_{16}$ inch—$^3/_{32}$ inch of the bottom. With $^1/_4$ inch or heavier, it is best to use two or more beads, scarfing from either one or both sides and leaving about $^3/_{32}$ inch unbeveled at either the bottom or center, as the case may be.

The 18–8 has a high coefficient of expansion, about 60% greater than mild steel. In setting up any job this must be taken into account and allowance made. If automatic welding is used, such as the carbon arc, the edges will be clamped parallel the same as with ordinary steel, extra allowance being made only when movement is calculated. If a ring is to be welded to a flat circular sheet and a corner weld used, the sheet will bulge at the center due to contraction around the outside on cooling. For this reason it is more important than with steel to

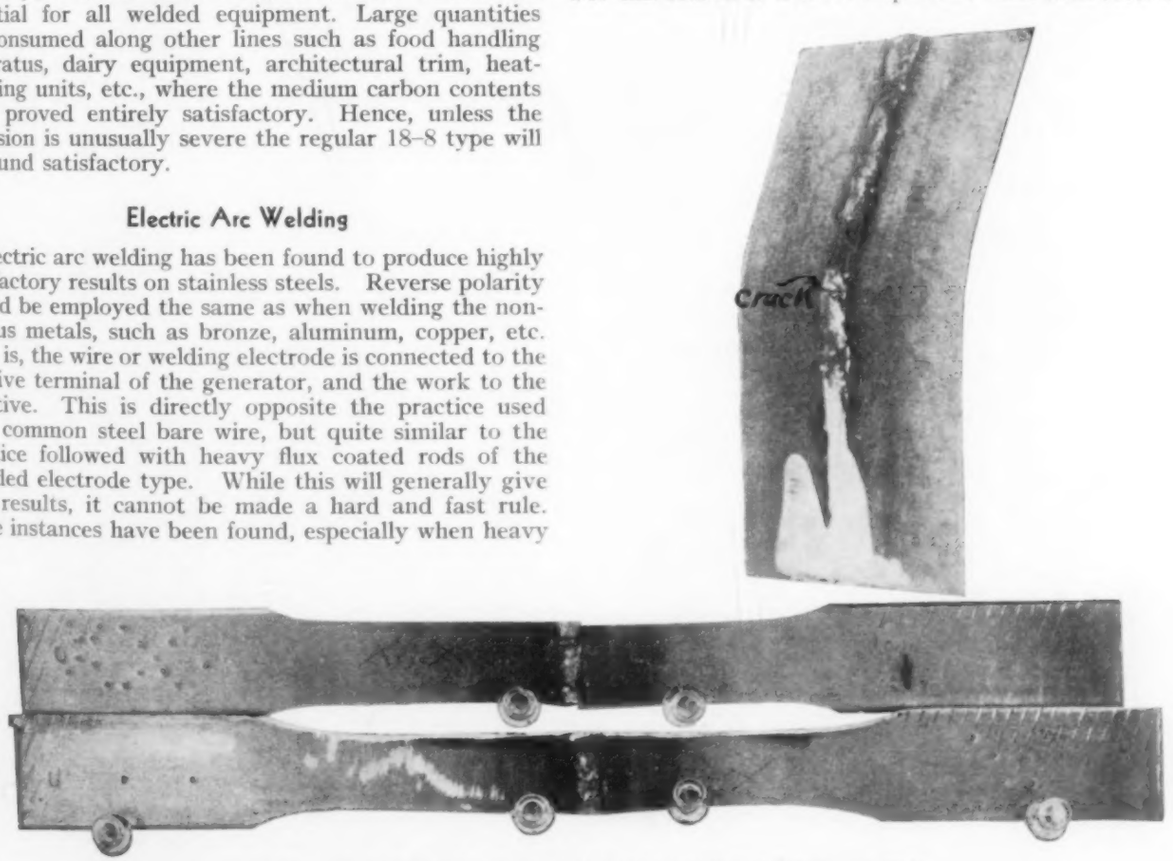


Fig. 10—Tensile and Bend Tests on 18–8 with High Carbon (1.86%). Note Brittleness in Weld

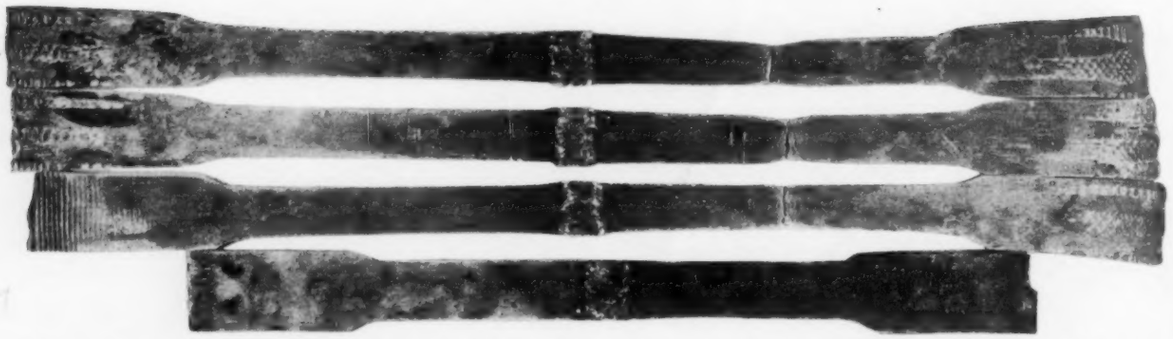


Fig. 11—Tensile and Bend Tests on 18–8 with Low Carbon (0.07% max.). Note Ductility in Tensile Tests and of the Weld Metal in the Bent Sections. Bend Test Is a 3/8-Inch Plate

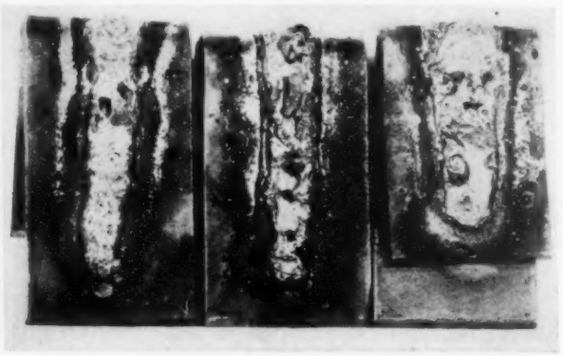


Fig. 12—18–8 Electric Arc Welds Made with Improperly Coated Welding Electrodes. Note Porosity in Deposited Metal Due to Insufficient Protection from the Air

turn a one- or two-inch flange around the sheet and then butt weld the ring or shell to it, which permits the weld to move slightly without producing a buckle. For the same reason, it is advisable to have proper fixtures for holding the work in place while welding to prevent localized strains pulling at the joints and drawing them out of line. This is almost sure to happen if an attempt is made to weld a curved seam without some such support.

In the fabrication of general tank work in which light plates are employed, two general methods have been found quite satisfactory. In one case the plates are clamped in a jig. This consists of a heavy base with a copper chill bar, a narrow shallow groove running lengthwise along the center of one surface. Pressure is applied by two long bars beveled at an angle of about 45 degrees along the edges facing each other making an opening of 90 degrees. The bars themselves are about 1 inch apart at the bottom and are so set that the groove in the chill plate will be in the center. The sheets to be welded are then clamped in this fixture with the polished side down, in the case of polished sheets, and the edges held slightly apart and placed over the groove. The clamps are then applied from the top holding the two edges in place while a weld is made from the unpolished or back side. The groove in this case acts as a mold holding the metal in shape to facilitate grinding in some cases, or merely to give proper reinforcing. This jig will be found satisfactory for flat straight seams. For circular or curved joints the same principle modified can be used, if economy as controlled by quantity production so warrants.

The second method used quite extensively, especially where a variety of shapes and sizes of products is made but not in sufficient quantity to warrant special fixtures, consists in fitting up the job for butt-welded seams and tack welding about every 2 inches on the back side. If any warping should occur, the joint can be straightened. A light weld penetrating about half-way through the sheet is then laid on the inside. A reinforcing bead is deposited on the outside, completing the weld. If grinding or polishing is required, the bead should be rough ground with either a bakelite or rubber bond wheel running about ten thousand feet per minute. When nearly flush with the sheet, cotton wheels set up with various sizes of glue and abrasive should be employed.

The 18–8 also possesses a lower heat conductivity than steel. This tends to keep the heat of the arc localized at the point of contact rather than allowing it to travel rapidly back into the plate. Due to this fact, together with its lower melting point, less heat is required for the same size plate and wire than is ordinarily employed. In other words, if 110–120 amperes were used with a 1/8-inch steel wire, we would need only about 90–100 on 18–8. Stainless will penetrate much better than steel because it is very fluid when molten, while ordinary steel tends to be more viscous and sluggish.

As previously mentioned, the alloys in Stainless steel are chiefly chromium and nickel, the balance being iron. These products are highly resistant to heat, that is, they will not scale appreciably at high temperatures as long as they remain in the solid form, but will burn as soon as molten if exposed to the air. The iron and nickel will remain practically unaffected but the chromium will oxidize rapidly. Hence, in welding it is necessary to protect the molten metal from contact with the air. In arc welding this is accomplished by applying a flux coating on the outside of the electrode which will fuse along with the wire. This protects the metal while going through the arc and covers over the deposited metal, excluding any air until the weld has solidified. If the coating is not of the proper type to afford the required protection, an imperfect or badly burned weld will result. If we should attempt to arc weld 18–8 with a

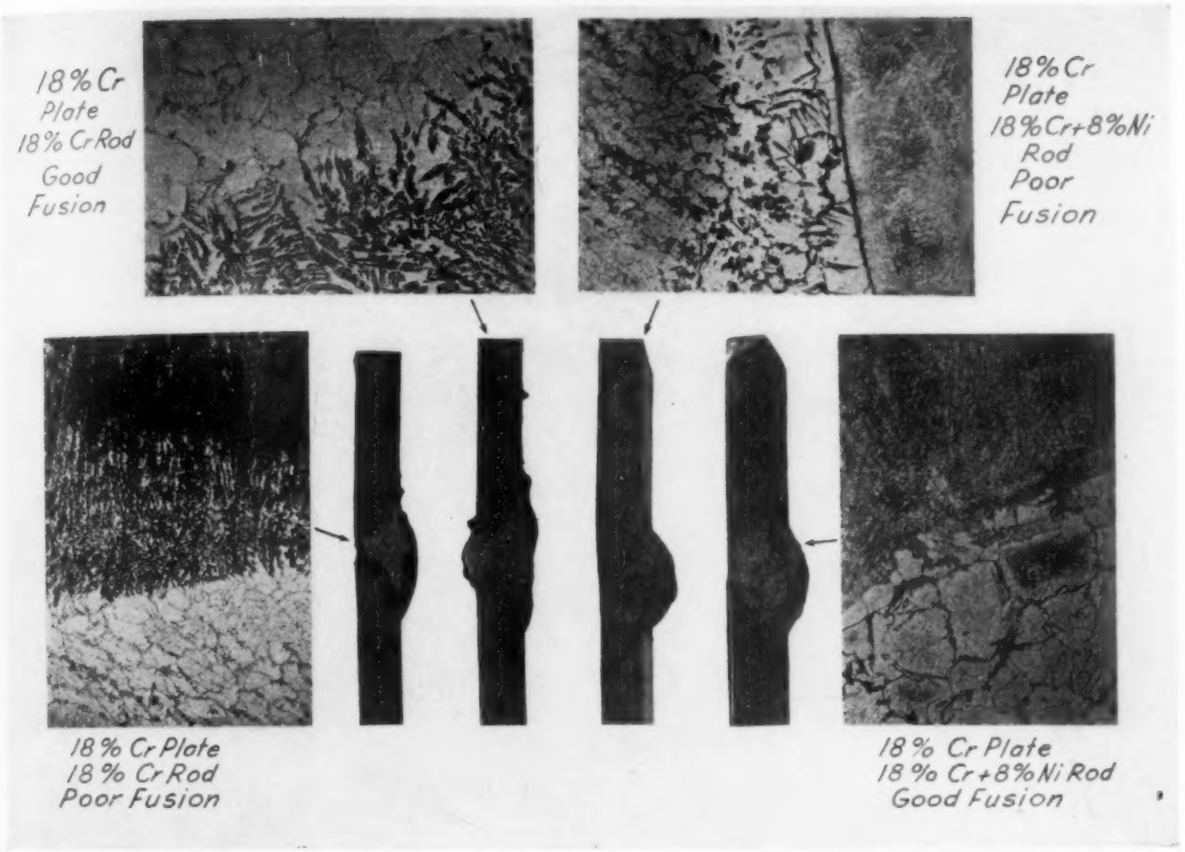


Fig. 13—Sections Cut Through Four Welds on 18% Chromium Plate, Using 18% Chromium and 18–8 Wire. (Lower Left) Note Fair Diffusion Between Weld and Plate When Using Same Metal Even with Lower Heat. (Top Left) Note Good Diffusion in Weld Properly Made. (Top Right) Note Sharp Line Demarcation Between Weld and Plate Obtained with Poor Fusion and Dissimilar Metals. (Lower Right) Note Better Diffusion Between Dissimilar Metals When Proper Heat Is Employed

bare rod of the same analysis a porous, leaky and generally bad-appearing bead will be produced. Figure 12 shows three representative welds made with coatings which do not have the above required properties. These welds were all deposited on solid plate, excluding any possibility of air coming up from the bottom.

In addition to protecting the metal, the coating should also have a stabilizing effect to assist in maintaining a steady arc. As the weld cools this slag covering will crack off to a large extent, due to difference in contraction between it and the metal. However, if a weld of more than one bead is to be made, all slag should be removed with an air hammer and caulking tool, or by some similar method, to guard against any being entrapped by further layers. This flux has a low melting point and any small particles remaining will generally be fused and floated to the surface by the heat of the next beads, but this should not be depended upon. This procedure will produce welds which on grinding and polishing will not show any blow holes, gas pockets or slag inclusions.

The flux which protects the metal must not contain carbonaceous material which will break down under the temperature of the arc and carburize the welded metal. Only 18–8–S should be used for electrodes and the carbon content of the deposited metal must be less than 0.08%.

If carbonaceous materials or high-carbon wire are employed, the resulting welds may also be high in this element and the ductility will be considerably reduced. Figures 10 and 11 show tensile and bend tests on such high-and low-carbon welds, respectively.

Whenever welding the stainless steels, the same analysis welding rod should be used as the plate to be welded. This will produce not only a better diffusion between the weld and plate at the junction of the two, but will also give similar corrosion, physical and chemical characteristics between the two. Figure 13 shows four welds made on 18% chromium plates, using both 18% chromium and 18–8 rods, with proper and poor fusion.

While there will be a sharper line or less diffusion noted between the deposited and base metal when 18–8 is used for both rod and plate than in the case of 18% chromium, there will be a good bond between the two when welding is properly done, as shown by the tensile and bend tests in Fig. 11.

In the straight chromium field the alloy containing 18% chromium, is the most common. This type requires the same procedure in welding as the chromium-nickel variety, the only difference being that less warpage is likely to occur, due to its low expansion, and that the welds will be hard and comparatively brittle, due to its martensitic structure. In the lower chromiums, such as 12%, the welds can be toughened quite well by annealing, but in the higher alloys with 18% or more chromium they do not respond satisfactorily to annealing or heat treating although if proper welding procedure is followed they can be softened to some extent by annealing for eight hours or so at 1450° F. These alloys at room temperature in the as-welded state are so brittle that they will snap at the slightest deformation. A good example of such welds is shown in Fig. 14.

While these welds will be brittle at room temperature, if raised to a few hundred degrees they will show considerable toughness, sufficient at times to bend about

90° before breaking. This is shown in Fig. 15. In this case the sample of carbon steel fire-box plate welded to 18% chromium stainless with 18% chromium wire, bent about 80° without breaking when heated to 400° F.

Due to its low coefficient of expansion, which is even lower than mild steel, 18% chromium is much less liable to introduce difficulties than the other type. In some cases this is the deciding factor in determining its use. It is this property, along with its high blue brittle range, that explains why it gives such good service in locomotive fire-boxes where the movement, due to expansion and contraction on heating and cooling, is considerably reduced. A pair of 18% chromium side sheets installed in a freight locomotive, after running 75,000 miles showed absolutely no signs of corrosion, buckling or cracking, while a set of regular carbon steel fire-box plates applied at the same time to another engine of the same type and operating in the same area, showed after 75,000 miles numerous radial cracks around the staybolts, deep corrosion around the mud ring and some buckling between the staybolts. Furthermore, very little scale adhered to the Enduro plate on the water side, compared to the mild steel. This was probably due to the lower expansion of the stainless causing the scale to crack off and be removed at each washing.

In this case the stainless was welded directly to the carbon steel. The operating temperature of this locomotive, around 500° F., is in a range where these welds are tough; hence, no trouble was experienced from this angle. Considerable difficulty might have been encountered if the operating temperature were around 100° F., as shown in Fig. 15.

Recently an entire locomotive fire-box, including side, crown, flue, door sheets and syphons, was fabricated from 18% chromium, using an all arc-welded construction. This locomotive to date has run more than 60,000 miles in a bad water condition and is giving no particular trouble. No corrosion or metal failures have developed and the scale on the water sides cracks off after each washout, maintaining a practically scale-free surface.

While it is best practice always to use welding rod the same as the metal being welded, it is sometimes necessary to deviate from this practice to a certain degree. For instance, if a patch were to be welded in a straight chromium plate and no provision for contraction were provided, it would probably be necessary to use a chromium-nickel wire, as the strain on the weld on cooling would snap a straight chromium bead. Due to greater strength and extremely high ductility, an 18-8 weld would hold. This practice has been followed in several cases with good results on straight or flat sections where the 18% chromium welds failed.

Fig. 15—(Left) 18% Chromium on 3/8-Inch Plate Shows Good Ductility, Bending About 80° When Struck with a Sledge in a "V" Block at 400° F. (Right) Same Weld Showing Brittle Break When Cold

The high temperature employed in welding, whether on chromium or chromium-nickel, will discolor the metal for a short distance on each side of the weld. This is a surface condition only, being nothing more than an oxide. It can easily be removed, either by some form of pickling or by grinding and polishing with abrasive wheels and grits, after which the metal underneath will be in the same condition as before welding. That is, the oxide on the surface does not affect the metal beneath it. If this oxide is not removed and the surface becomes wet and dry, it will change from a blue color to a brown, resembling iron rust, along these areas. This likewise will be a surface condition only.

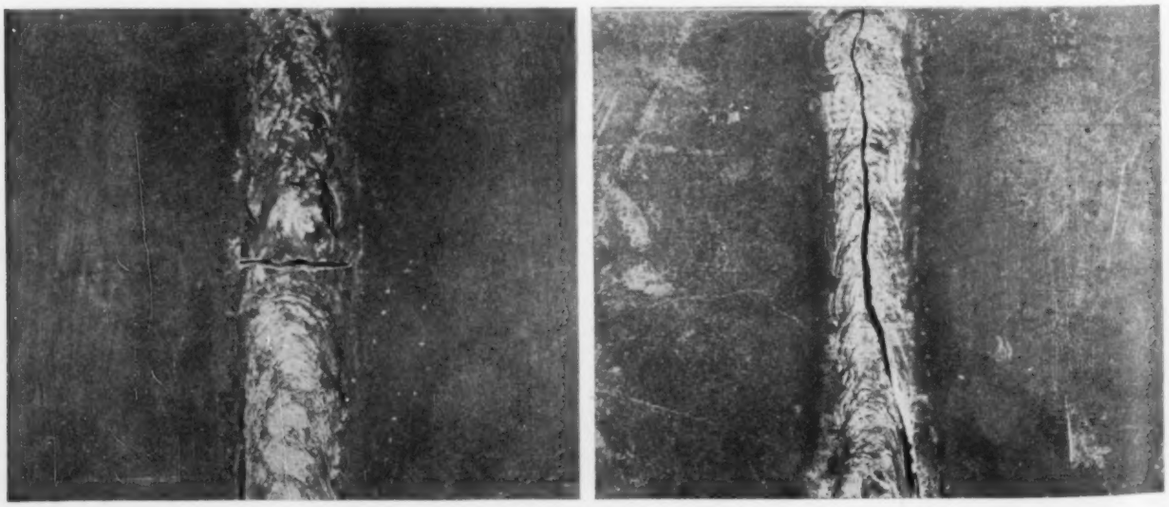


Fig. 14—18% Chromium Weld on 1/4-Inch Plate Showing a Brittle Break at Room Temperature

Fig. 16—Tanks of Enduro Stainless Steel Arc Welded. Used as Gas Crackers in a Steel Mill

Gas Welding

Gas or acetylene welding is used quite extensively on stainless steel, especially in the lighter gages, such as 18 gage and thinner. Gas welding, of course, is slower than the electric arc method and therefore apt to produce considerably more buckling and warpage. However, it is difficult to arc weld lighter than 16 gage in many cases; hence, gas welding is employed in this range.

The flame used should be as small as possible, supplying just sufficient heat to produce good fusion. Any excess heat will simply aggravate buckling to a greater degree. The ideal flame adjustment would be exactly neutral, but, since this is rather difficult to maintain at all times, it is advisable to use a slight excess of acetylene. While there are regulators on the market today which will hold a neutral flame quite closely, there are many other less accurate types which have been in use for a long time. It is, therefore, a good policy to use a slightly reducing flame as a general practice. The object of this is to develop an atmosphere around the molten metal, protecting it from the air just as the flux did on welding electrodes. If too much acetylene is used, that is, if the flame is too highly carburizing, excess carbon will be introduced into the weld metal, making it weak and brittle. On the other hand, if the flame runs oxidizing, due to too much oxygen or too little acetylene, the weld will appear badly burnt and be quite porous. When properly adjusted for a slight acetylene flame the feathers as noted on the end of the inner blue cone should not be more than about $^1/_{16}$ inch long. This will give sufficient protection against variations in pressure under average conditions to insure solid welds and at the same time will not load up with carbon.

Fig. 18—Airplane Exhaust Collector Ring Gas Welded of Stainless Steel, Type 18-8-S-Ti

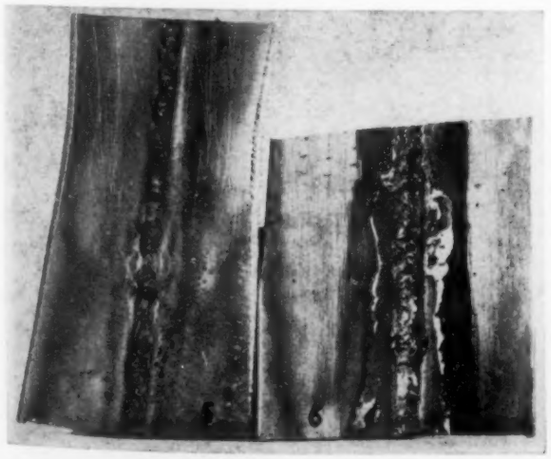


Fig. 17—(Left) Bottom Side of Gas Weld Without Flux. Weld Is Rough and Porous. (Right) Similar Weld Using Flux. Note Smooth Uniform Bead Along Center

Although this flame will protect the upper side of the weld, it will have no effect on the under side. It is necessary, therefore, to apply a flux along the bottom side next to the edges. This flux is generally easiest to apply by making into a water paste about the consistency of molasses and allowing to dry a few minutes after applying, or long enough to permit it to become fairly solid before welding. As soon as the heat is applied this flux will fuse, forming a sort of mold to cover the bead and at the same time to protect it on the under side. This will produce a smooth, neat-appearing bead, whereas, without the flux it will be rough, irregular and will present a generally burnt or bad appearance.

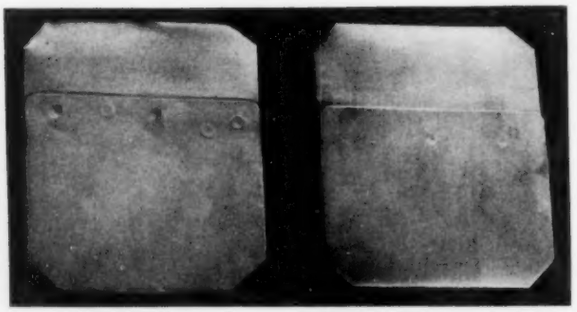


Fig. 19—(Left) Spot Welds on 18-8 Showing Depression. (Right) Indentation Reduced by Use of Copper or Aluminum Block Between Electrode and Sheet

In setting up the job for gas welding it is advisable wherever possible to clamp the sections in a jig to hold the edges in line with each other. In this case the flux paste should be applied to the under side and allowed to dry at least partially before clamping in the jig. If the edges are held apart approximately half the thickness of the sheet, good fusion and penetration can easily be obtained merely by holding the flame directly against the work, allowing the edges to melt and fuse with the filler rod. The rod should be held in the flame at all times, at least in the protective gases, to prevent the air oxidizing the molten globule on the end of the rod before it is dropped into the weld. The weld metal should not be puddled with the end of the rod, as is frequently the case with ordinary steel.

In the event a jig is not available, as is frequently the case when many products of various shapes and sizes are manufactured, the joint should either be butted together straight or the edges may be raised slightly toward the outside. The flux, however, should be applied to the bottom side, as before. The joint should then be tack-welded every couple of inches, realigned if necessary and then finish-welded the same as if in a jig. This may cause greater buckling than when a jig is used, but if care is exercised in the design of the joint and if the rate of welding is rapid, it generally can be held well within usual limits.

The flux may also be applied on the top of the weld, as well as on the bottom, or on the wire itself. However, it has been found in the majority of cases that the best results were obtained by applying it only to the bottom side and using a bare wire of the same analysis as the plate for the filler rod. Figure 17 shows the bottom sides of two gas welds on 22 gage stainless steel. In the one case no flux was used and the weld is pretty well burnt and porous. The other is smooth and solid.

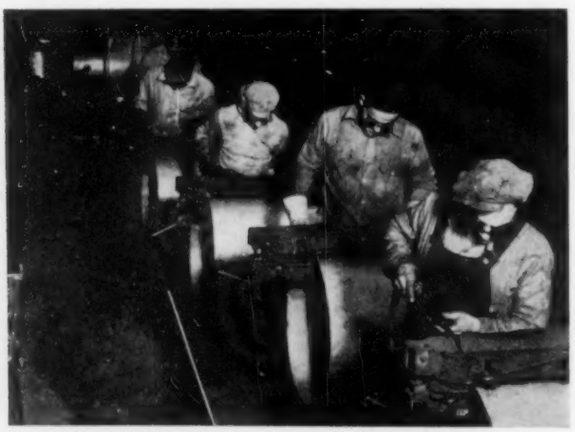


Fig. 20—Gas Welding Stainless Steel Liners for Food Shipping Drums

While gas welding is confined chiefly to the lighter gages it should not be considered as impossible on heavier sheets, providing the proper fixtures for holding the work are available to prevent buckling. Figure 18 shows a good example of a gas-welded Enduro 18-8-S-Ti airplane exhaust collector ring. Light gage sheets are used to form the sections and then welded along the outside to themselves and to the flanges.

Spot and Projection Welding

The stainless steels are particularly well adapted to spot welding because of their clean surface, freedom from any oxide or scale, and because of the absence of any coating such as zinc or lead, as on galvanized or terne plate stock.

Spot welding, in principle, is nothing more than holding two sheets in close contact between two copper electrodes about an inch or so in diameter with the contact ends tapered to about $^1/_8$-inch in diameter, and passing a current low in voltage but high in amperage through the circuit for a short period. Fusion immediately takes place between the two sheets, while the excess heat is raipdly carried away from the outside surfaces by the water-cooled electrodes. The low voltage, about 2 to

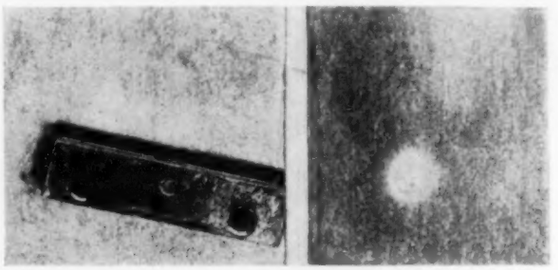


Fig. 21—(Left) Indentation on Lower Side of Projection. (Right) Opposite Side After Projection Welding. Note Comparatively Smooth Surface at Weld Practically Level with Rest of Sheet

4 volts, is obtained from a step-down transformer wound in sections, each being connected with a stop on a rotary control switch by which the current or heat can be increased or decreased by turning up or down, respectively.

While the total heat applied will be determined by the rotary adjustment, the area of the electrode points should be maintained as near constant as possible. Any increase in area will tend to reduce the heat per unit area, resulting in an improperly or poorly fused joint. A decrease in area will increase the unit heat and will usually burn a hole entirely or partly through the sheet to be welded, other factors remaining constant.

The pressure exerted by the electrodes is generally produced by the compression of helical springs and can be adjusted by a lock nut on a shaft through the center of the spring. Variable pressures will also affect the quality of the weld. Too much pressure will reduce the resistance of the joint and hence tend to decrease the heat generated. The pressure generally determines the amount of upset displacement directly following the fusing period, producing an indentation on each side of the sheets welded.

In addition to these variables, the time of current flow is of great importance. Too long a period gives the same result as too much heat. Too short a contact will produce no weld.

It is evident, therefore, that spot welding depends on the following four variables:

1. Current (controlled by rotary switch).
2. Diameter of electrode contact points.

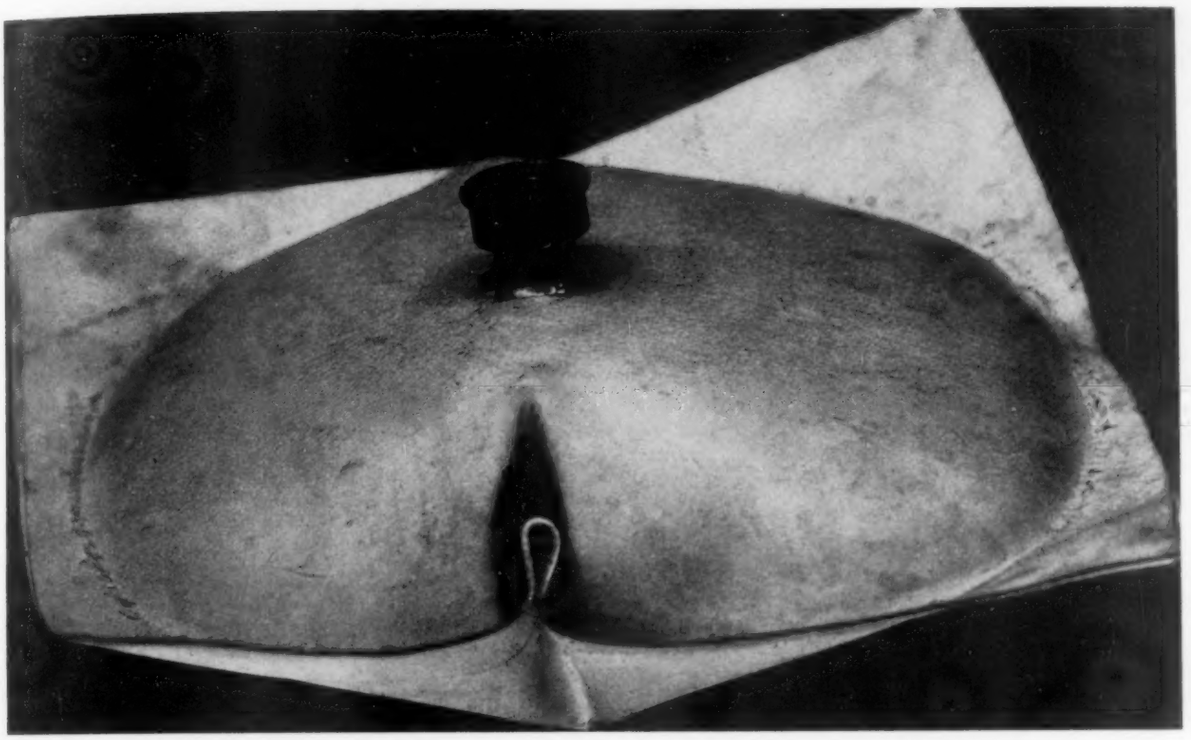


Fig. 22—Two 18-8 Flat Sheets Seam Welded and Blown Up by Hydraulic Pressure. Welds Did Not Leak

3. Pressure (controlled by spring or pneumatic pressure).
4. Length of time the current is allowed to flow.

While it would not be impossible to determine an adjustment of each of these with respect to the other for each gage to be welded, as in the case of automatic machines where time and pressure are accurately controlled by motor-driven cams and the current set by hand, it would be next to impossible to determine an adjustment for manual operation, due to the personal element. Furthermore, such adjustment would be necessary for each individual machine. This makes it impossible to set up any specific procedure to follow for this class of work. However, the Stainless steel in general will require less heat than the same gage in common steel, due to its lower heat conductivity (tending to concentrate heat in one spot), its lower melting point, and the better contact resulting from a scale-free surface. Consequently, if an operator is producing good work on, say 20 gage black steel, he could, in general change to the same gage Stainless steel either by dropping the switch one point or reducing the time slightly or both. More definite instructions cannot be given but the exact procedure must be worked out individually, balancing one variable against the other until the desired result is obtained. If both electrodes are of the same diameter, a depression will occur on both sides which, while not serious on the pickle finishes, may be objectionable on the polished surfaces. This can be reduced by using a copper block about $1/2$ inch thick and 2 inches square between the electrode and polished side, thus putting the major depression on the lower side. An aluminum block $1/8$ inch to $1/4$ inch works well in some cases but, due to its lower melting point, will tend to pit if a slight arc is drawn. This procedure will reduce the depression but will not eliminate it entirely, because it is due to shrinkage of the molten metal in the center and, hence, pulls from both surfaces, as shown in Fig. 19. The indentation remaining, if the work is to be polished, will have to be ground out with a cotton wheel set up with glue and abrasive of about 80 grit or finer.

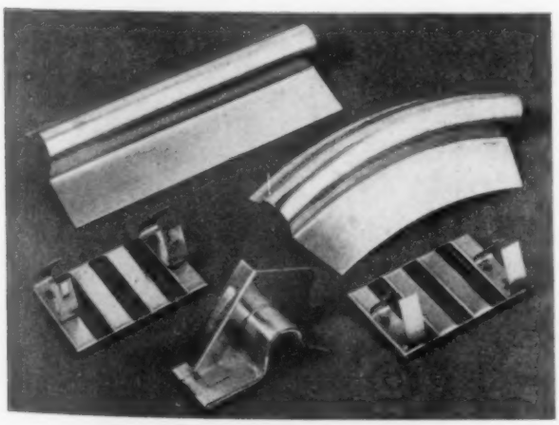


Fig. 23—Stainless Steel Oil Burner Parts Spot Welded

Projection welding is a form or variation of spot welding in which small projections or buttons are raised on one side of a sheet or plate at the spots where it is to be welded to another sheet. When these two plates are put together and placed between the electrodes and pressure applied, the projections themselves act as pointed electrodes in localizing the heat. In this way numerous welds are frequently produced between two sheets in one operation. The projection as originally made will, of course, have a depression or deep indentation on the one side. This will still be present in the finished weld, but due to its greater depth in comparison to one side of a spot weld the opposite side will as a general rule tend to produce a more even surface than the average spot weld as noted in Fig. 21. When welding polished Stainless, it is advisable to place the welds in the least conspicuous positions, as often it is difficult to refinish

Fig. 24—Freezing Shelf for Mechanical Refrigerator, Fabricated by Combination Spot and Seam Welding of Two Sheets of Stainless Steel

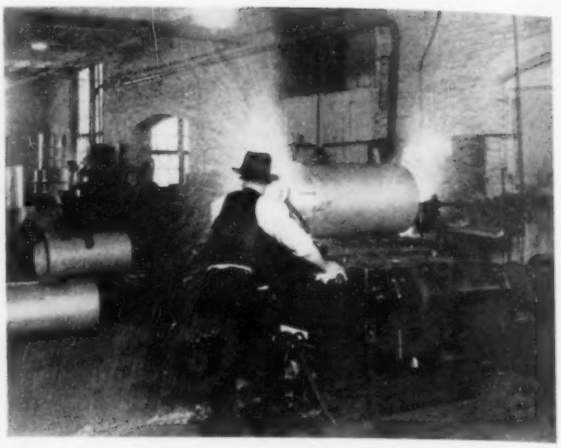


Fig. 25—Production Flash Welding on Beverage Shipping Drums Made of Stainless Steel, Type 18-8-S

the welds and have the same color if the whole piece is not refinished. This depends, to a great extent, upon the finish of the sheets.

Spot welding, like any other type of welding requiring high temperature, will form an oxide on the surface which will be blue in color. If this is exposed to the weather or moist conditions it will slowly change to a brown color resembling rust. This is merely a surface condition, affecting the original oxide only. If such welds are to be exposed to the atmosphere, they should be cleaned either with acid, as in pickling, in the case of No. 1 finish sheet, or ground and polished, if No. 4 or higher finishes are employed. In the ground and polished state, spot welds have withstood several hundred hours salt spray without the least sign of attack.

Shot welding is also a form of spot welding but employs a higher voltage and shorter time, producing less heat on the surface. It tends more completely to confine the heat to the junction of the two sections being welded. The method, therefore, produces less oxide or discoloration in general on the surface than ordinary spot welding.

Spot and projection welding are used extensively where a firm bond or joint with good physical strength between two sections is desired, but where water-tightness is not a factor. A good example of this is noted in Fig. 23, showing several spot-welded oil burner parts.

Seam Welding

Seam welding, frequently known as resistance or line welding, is similar to spot welding in principle. Instead of using two electrodes in making one weld at a time, a roller is applied on both electrodes and the work is fed between these, as a continual series of intermittent welds is produced. Various machines employ different methods of producing this intermittent effect, but in nearly all cases the resulting weld is a series of overlapping spot welds, as can be noted by a stitch effect on the surface. The adjustment or manipulation is similar to that for spot welding. It should be remembered, however, that the range for welding the chromium and chromium-nickel is considerably more narrow than common steel and because of this a closer adjustment is of vital importance.

Water-tight welds are produced by this method as shown in Fig. 22. This shows two flat Stainless 18-8 sheets seam welded together around the outside. A pipe coupling was soldered over a hole drilled in the center of one plate. Hydraulic pressure was applied and plate blown up as shown without a leak appearing in the weld.

This type of welding is used extensively in the manufacture of light sheet metal containers or packages. Figure 24 shows an evaporator for a mechanical refrigerator made by seam welding 18-8-S sheets.

Flash Welding

Stainless steel can be flash welded much like ordinary steel products, provided certain conditions are observed as noted before. In this type of welding the two sheets or bars to be joined are held in grips approximately $\frac{1}{2}$ inch or so from the edges, depending on the section. The current is turned on, the edges brought together and a certain amount flashed off, during which period the metal is coming up to welding heat. At the proper time the current is shut off and the two edges squeezed together or upset, producing a burr along the outside which, when ground or chipped off, shows a solid weld beneath. A close adjustment of all these operations is very important with stainless as compared to ordinary steel. For instance, if the metal is too hot or the time between the flash and upset is too long, part of the metal will flow away like water, leaving a hole in the finished joint. In producing the actual upset the first stage should be very rapid followed by a slower movement than with steel. This will keep the very fluid nearly

Fig. 26—Insulated Beer Barrel with Inner Shell of Stainless Steel Welded by the Atomic Hydrogen Method

molten metal from dropping away at first and the slower and final movement will allow the metal to upset evenly instead of crawling irregular from one side to the other. When conditions are right, this joint will be solid. It is necessary, therefore, that automatic control of all stages be employed. The two edges along the joint should be as uniform and straight as possible in order to start heating or flashing along the entire section at the same time to prevent over-heating or loss of metal at any one point, as would be the case if contact were made at one end of the joint much earlier than the other. The grips should also be in good mechanical condition to prevent climbing, especially with thin sections. Generally speaking, here, as in spot welding, less heat or shorter time will be required than with common steel of the same section. Figure 25 shows a stainless steel beverage shipping drum being flash welded and trimmed.

Atomic Hydrogen Welding

In this method of welding a stream of hydrogen is passed through an electric arc between two tungsten electrodes. This effects the break down of the molecular hydrogen into the atomic state with the absorption of a large amount of heat. As it leaves the influence of the arc it reverts to the molecular state and gives up the absorbed heat while it is in contact with the metal to be welded which is then fused by the heat evolved. The hydrogen itself burns, thus generating more heat. During the process the hydrogen offers excellent protection to the molten metal, excluding any air coming in contact with the weld. This method is well adapted for stainless steel welding. It works well either with a filler rod or by fusing the edges of a joint when butted together without any additional metal.

Automatic atomic hydrogen welds on stainless steel under proper control will develop an even, smooth, sanitary surface on the opposite side, cleaning readily with only a pickling operation. Figure 26 shows a Stainless steel inner shell beverage shipping drum welded automatically with atomic hydrogen.

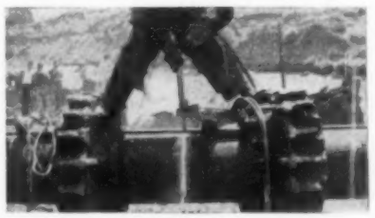
Brazing and Silver Soldering

Stainless steel can be brazed or silver soldered satisfactorily by using proper fluxes. Ordinary steel flux or borax will not successfully remove the scale formed on the surface when heated and hence will prohibit any bond between the solder and the steel. The solder will ball up resembling water drops on an oiled surface and will not adhere. Special fluxes for Stainless steel are on the market which, when used dry or in a water paste applied to the surface before heating, will eliminate this difficulty because they will fuse and protect the steel from the formation of an oxide on it.

Low melting silver solder is to be preferred over those melting at higher temperatures because it reduces the tendency to form scale and also reduces warping. It is advisable to heat the rod and apply dry flux, as is the general practice, in addition to the original paste or dry powder on the steel itself. Care not to overheat the metal is necessary because copper alloys will penetrate entirely through the sheet following the grain boundaries, resulting in checks or cracks upon cooling. The straight chromium Stainless steels are not so sensitive to this condition and seldom check because of copper penetration. When using the chromium-nickel type it is recommended that only the low-carbon product be used in order to reduce or eliminate this tendency. Figure 24, the tubular connections are silver soldered to the Stainless steel evaporator shell.

In the comparatively short time that these Stainless steels have been produced on a commercial scale their uses and applications have grown rapidly, largely as a result of the ease with which they can be fabricated. Welding has played a large part in this development.

"Hand Operated Cutting Torches Retain Their Unlimited Application Scope"



By E. L. MATHY*

WHETHER the welding process involves the electric arc, the gas welding torch or any one of numerous automatic welding processes—the cutting torch remains the universally required tool. If one were to consider the perpetuation of modern construction, maintenance procedure, dismantling operations or design simplicities without the availability of a suitable cutting torch, one would have to recognize that industry would be obliged to give up virtually all of the advantages gained during the past quarter century.

Illustrated in the two accompanying pictures is the scrapping of a 60 foot long, 21 inch diameter, propeller shaft which was taken out of the old ship 'Contra Costa.' The dismantling and scrapping operations were conducted by J. F. Petersen of Antioch, California. Note particularly the engraving illustrating how smoothly the cutting torch permits a straight cut through the center of this 21-inch diameter shaft."

* Vice-President, Victor equipment Co.

To Carry Aggregate and Cement Across the River from Eastmix to Westmix a Light Suspension Bridge Was Built. The Gravel Conveyor Is in the Bridge and Above It Is the 10-In. Welded Pipe Line for Dry Cement

Grand Coulee Dam

By A. G. WIKOFF*

The World's Greatest Dam Is an Inspiring Example to Contractors the World Over

TONS of paper and gallons of printing ink have been used up in the past two years by the newspapers and the technical press in efforts to describe adequately the amazing dam construction project in the Grand Coulee. Its size alone beggars analogy. Its potential benefits are said to be of astronomical proportions in terms of dollars and cents; what economic advantages it is expected to provide in cheap power, irrigation and land reclamation lie in the future dreams and hopes of millions of people. These things will be more determinable in about 50 years.

Today the important phases of the construction work are being watched by contractors and engineers the world over, so that they may learn every detail of the modern methods and techniques being applied to this work.

Project Beggars Description

A general picture of the dam construction work is, of course, necessary for an intelligent understanding of the varied applications of the oxyacetylene process.

The Columbia River, 1210 miles long, flows in general, southwest across the State of Washington. It drains a watershed of 259,000 square miles, an area roughly equal to that covered by the States of New York, Pennsylvania, Ohio, Virginia, West Virginia, Delaware, Kentucky and Maryland. In the 700 miles of its travel through Washington it falls about 1300 ft., giving it tremendous power potentialities. Boulder Dam handles the Colorado River's maximum flow of 300,000 second-feet, while the Grand Coulee will handle a maximum Columbia flow of 725,000 second-feet. The average annual runoff of the Columbia at Grand Coulee is 79,000,000 acre-feet—more than five times the annual runoff of the Colorado at Boulder.

Such tremendous flow will give the Grand Coulee a power capacity of 2,520,000 hp. as compared to Boulder's 1,733,000 hp.

The dam structure, four times the bulk of the Great Pyramid, will have a mass of 23,000,000 tons necessary to impound an artificial lake of 9,500,000 acre-feet of water. Its length will be 4300 ft., its base width 500 ft., its height when completed 550 ft. and the surface backwater of the lake behind it 151 miles.

Construction Problems

Design and construction of the dam have presented problems never before attempted. New types of machinery had to be built, and the exercise of ingenious engineering skill was mandatory. This great river, 700 ft. across, 70 ft. deep, flowing as fast as 14 miles per hr., has had to be wrested from its ancient channel and made to flow through man-made by-passes while the dam foundation was being built.

A steel cofferdam 3000 ft. long had to be sunk to bedrock. A mountainside of earth—15,000,000 cubic yards of dirt and rocks—is being transported more than a mile and raised 600 ft. by endless belt conveyors. Thousands of tons of greasy earth had to be frozen in place by artificial refrigeration to prevent a serious landslide.

An ingenious network of belt conveyors was provided to carry prepared aggregates of sand, gravel and cobble-

* The Linde Air Products Co.

Practically All Piping for General Service Is Fabricated by Oxyacetylene Welding

stones to the mixing plants, likewise constructed for this job alone. These plants are known as "The Houses of Magic." The huge machinery weighs and mixes 8000 cubic yards of mixture each day. There is also the gravel plant a mile from the damsite. Specially designed and fabricated machinery sorts and washes many thousands of tons of sand and gravel daily.

In the fabrication and maintenance of all the special machinery, the hundreds of trucks and tractors, the pipe lines for water and for dry cement, steel working structures (larger than many great bridges) over the dam itself, the building and removal of the cofferdams, and the thousands of other miscellaneous kinds of essential equipment, the blowpipe has proved to be of the utmost value as a tool for the construction engineer.

The Cofferdams

The cofferdam on the West bank, 125 ft. high and larger than any ever before built, was a 3000 ft. row of circular cells each 50 ft. in diameter. Sheet steel interlocking piling was driven to bedrock. Standard 80-ft. mill lengths were too short for the required height and had to be extended by the addition of 45-ft. lengths. About 35 operators were employed on this work cutting the piles to the correct length. The shaping and fabrication of steel reinforcements for this was a considerable job in itself. Speed was all essential in order to finish before the spring high water.

Later, two cross-stream cofferdams had to be constructed. These were rock-filled timber cribs faced with sheet steel. Little oxyacetylene work was required on this section except some cutting for the fitting of the facing.

Another steel cofferdam 100 ft. in height from the surface to bedrock, and about 72 ft. in length was constructed in order to carry out a repair job on the East side of the pier to the highway bridge.

The Gravel Plant and Conveyors

A hundred-acre glacial deposit $1^1/_2$ miles from the damsite provides the aggregate sand and gravel for the mix. Power shovels gouge out the deposit and spew their loads into huge shape-cut and welded conveyor mouths. Grizzlies fabricated by welding, and hard-faced to increase their life, remove oversize stones. The rest of the aggregate is carried downhill to the gravel plant. Crushing, screening, washing and de-watering of the material are carried out in the gravel plant and then the material is stored to await mixing.

Hoppers of steel plate were entirely shape cut and welded. Liner plates for the hoppers were hard-faced to increase their resistance to the severe abrasion.

A multitude of machine parts both on the conveyors and in the gravel plant such as gears, rings, thrust-bearings and collars, and sheaves are being constantly rebuilt with bronze-welding rod for replacement service. Wherever wear is specially severe, the part is hard-faced. Dipper teeth are examples of this. Broken castings and structural steel parts of the plant are welded in repair. Derrick and crane booms are heated and straightened. A complete list of welding and cutting work that is constantly being carried on in this division would be practically a glossary of names of all the machine parts used on this project.

Eastmix and Westmix

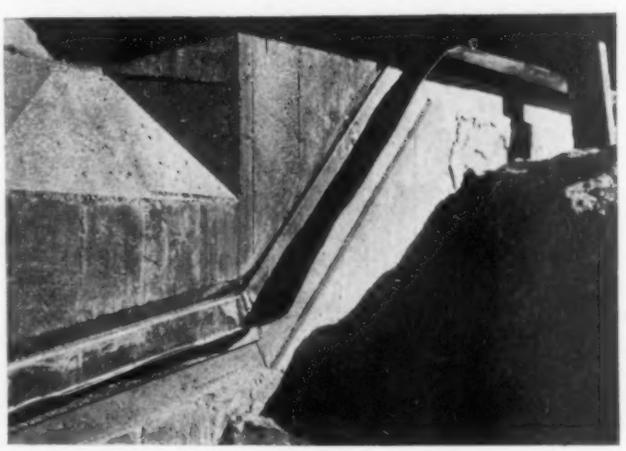
The sorted and graded gravel, rocks and sand are carried by conveyor and suspension bridge to either one of the two "Houses of Magic," Eastmix and Westmix, in which the aggregate becomes concrete. Great bins for storing gravel, sand and cement feed these parts of the mix into weighing hoppers, and in turn to the huge revolving mixers. All control of quantities is by electricity as is, in fact, the entire operation of the plants. The two mixing plants together turn out a total of 24,000 tons of concrete per 24-hr. day.

The part played by the welding operators toward keeping these amazing plants in operation day and night is similar to that of a hospital staff. Important emergency breakdowns call forth the welding crew to make immediate repairs. Minor ailments of individual parts of the equipment are cared for at the central welding shop—gears, brackets, beams, rollers, dogs, shutes, housings, motor frames, shafts, cams, booms and piping are among the ordinary patients. Where such incessant abrasion and impact exist any machine part may require rebuilding, straightening, replacement or repair at a moment's notice. Bronze-surfacing and hard-facing are important and continual operations. Steel welding and bronze-welding for broken parts is constantly "on the go." Portable welding and cutting equipment is out all the time mending, fixing and helping to keep the plant going.

The Dam

Concrete from the "Houses of Magic" is carried in hopper-bottomed buckets on flat cars out on the trestles over the dam and lowered by cranes to the forms below.

Layer Upon Layer of Concrete Is Being Poured to Form Great Blocks. When the Gaps Are Filled the Spaces Between Each Block Must be Grouted. Strips of Bronze-Welded Copper Are Placed During the Pouring to Keep the Grout from Seeping out. In the Picture Below a Detail of a Grout Strip Shows Why Welding Is Necessary



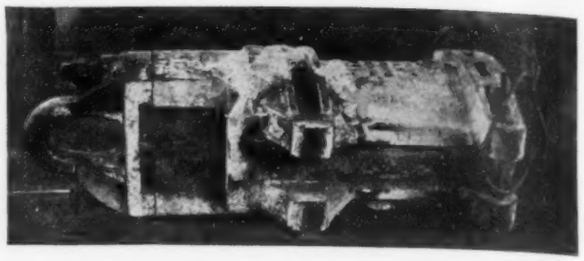
The block system of building the structure is being used in order to simplify the dissipation of heat from the hardening concrete. When the concrete cools it shrinks and contracts. The blocks lock into each other and at the same time minimize cracking. The cooling of the mass is accomplished by the same method that was used at Boulder Dam. Each block contains a network of pipe, about 400 miles of it altogether, through which cold river water is passed. Thus thirty days finds the concrete cold, whereas without this system several years would be required. All joints in the many headers used for this system have been made with the blow pipe.

As the concrete blocks cool, they shrink. The interstices between the blocks are filled later with grout which hardens and unites the structure into a solid monolithic mass. To keep each batch of grout in its predetermined area between the great blocks, and so that it will not seep out where it is not wanted, strips of 20-gage copper are nailed to the forms. These flange out, some in a vertical and some in a horizontal position to act as retaining strips for the grout. Corners and joints are all welded to provide watertight connections. Special small oxygen and acetylene cylinders that can easily be carried on the backs of operator and helper are used, one to a man. Thus, the equipment is entirely portable. High-strength bronze-welding rod is used for this, both to increase the speed of the work and to assure strong joints.

The General Repair Shop

A general or central repair shop is maintained and staffed with a regular crew of operators. Oxygen is supplied from manifolded cylinders, and acetylene from generators. Both gases are piped to station outlets in the shop and other strategic locations.

All kinds of welding and cutting jobs for repair and maintenance are carried out at this shop, which is in addition to welding equipment and operators working in connection with other parts of the project.



A Bronze-Welded Repair to a Cracked Pile Driver Cylinder Is Typical of Much of the Repair Work

Excavating equipment naturally requires a great deal of work. Booms are repaired and straightened, shafts of all kinds repaired, straightened and rebuilt when worn; gears are rebuilt; fractured castings for pumps, engines, motors, and a great many other kinds of machinery are repaired by bronze-welding. Dipper teeth are repointed and hard-faced. Pipe specials are fabricated. Special fabrication work to meet the demands of such a vast project is in constant demand.

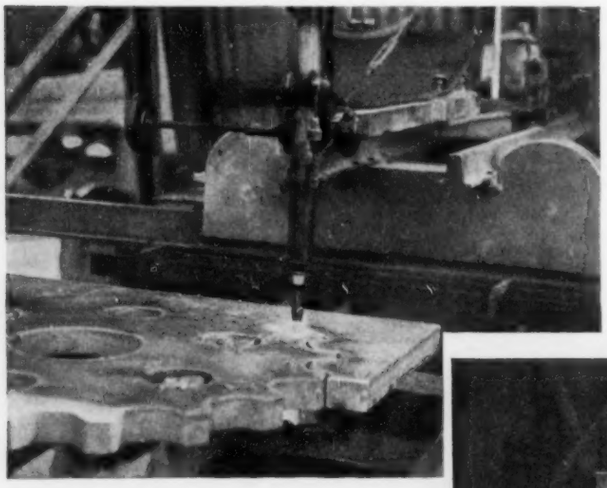
It is interesting to note the extensive use made of cutting machines for much of the fabrication work. Several small portable cutting machines provide ready means for cutting stock material to size in the most economical manner. A full size shape cutting machine is kept busy turning out gears, sprockets, hooks, pins, blanks, cams, rings, pipe flanges, wrenches, levers, washers and hundreds of other needed parts.

Pipe Lines

Another important phase of welding work at the Grand Coulee is the fabrication of pipe lines for all kinds of services. Of major interest is the 10-in. diameter dry cement line. Coulee takes from fifty to sixty carloads of cement a day, a large part of the output of five Washington companies. It is removed from the trains by a rotating disk and stored in eleven 5000-barrel silos. The dry cement pipe line carries the material under forced draft from the silos to Eastmix. Cement for Westmix is carried on through the pipe line over a suspension bridge across the canyon.

Another important line is the 16-in. water line from Mason City which supplies water to the gravel plant for washing gravel. This line, like all the others, was welded with High Test steel welding rod for greatest reliability and joint strength.

In addition to these, there are thousands of feet of welded pipe lines of varying lengths, sizes and for various services.



Gears and Sprockets, Among Other Things, Are Constantly in Demand. The View Above Is Typical Because It Shows the Shape Cutting Machine Turning Out a Sprocket for Use in the Complicated Machinery of the Gravel Conveying Equipment. Just to the Right of This Picture Several Standard Templets Are Shown. These Guides for the Cutting Machine Reveal Some of the Parts That Are Frequently Needed

For the Auto Body "Doctor"

By E. R. MECLEARY*

Airacetylene Torch Particularly Suitable for Use with Auto Body Solder

QUITE recently the airacetylene torch has been used successfully for applying body solder during repairs to damaged automobile fenders and body panels. For a good many years body workers have been using the oxyacetylene flame for this work. This is a speedy and economical method. Due to the intense and concentrated heat of the oxyacetylene flame it is necessary to hold the flame at a considerable distance from the body of the car to prevent overheating of the metal or any possible woodwork or upholstery that might be on the inside of the body. The airacetylene flame, not having the tremendous heat of the oxyacetylene flame, has been found to be ideal for this work. The heat is more spread out and less intense. For the flowing on of body solder on vertical surfaces it is particularly recommended. It flows the solder rapidly, and the tip of the flame can be touched to the car with no possible damage to the metal.

The standard plumber's type of airacetylene torch has already been enthusiastically received by those shops that have tried out this method. Many of the body shops are using the small dissolved acetylene portable tanks, sometimes known as "auto light tanks," although others have used the torch from a standard industrial cylinder of acetylene provided with a suitable pressure reducing regulator.

Equipment Entirely Portable

The portability of the small tanks used with the plumber's type outfit is an important feature. The use of this equipment as an auxiliary to the regular oxyacetylene welding equipment means that this latter apparatus need not be removed from regular welding and cutting operations in the shop.

Practically every time an automobile fender or body is damaged it is difficult if not impossible to pound out every dent. In many cases it would be necessary to remove a large amount of upholstery before the dents could be pounded from the body or doors. For this reason body solders have been developed and are in general use.

The Airacetylene Flame Is Rated "Tops" for Flowing Auto Body Solder on Vertical Surfaces

Field Use Shows That This Body Solder Method Cuts the Cost for This Work in Half

The method of using this solder in conjunction with the airacetylene torch is as follows: First the surface of the car to be repaired is thoroughly cleaned by filing or with emery paper. An accepted and popular method is to heat the metal slightly with the airacetylene torch, and then use steel wool and flux to rub the surface clean. The flux used is a special kind well known to the automotive repair trade. It has the effect of helping to clean and at the same time of tinning the surface when it is rubbed on.

It is a simple matter to make the body solder adhere to the metal which has been tinned in this way. If a large dent is to be filled, a wooden block is used to push the molten solder into its proper position.

Cuts Costs in Half

Those who have used the airacetylene torch for this work credit it with practically cutting the cost of such body work in half. This is particularly true in working on vertical surfaces or for working-in large quantities of solder where too much heat would cause the solder to break loose and drop to the floor. It is also said that there is less chance of rust on the body of an automobile which has been properly tinned and soldered in this way.

An additional use of this torch in connection with body repair work is on doors and panels which have been bent or sprung. In many cases an application of the airacetylene flame in a circular fashion to the sprung portion will cause it to spring back almost if not all the way to its original position. It is then a simple matter to fill up the dent with the body solder. This job is finished before it would be possible to take out the upholstery and fix it in any other way.

In those cases where the metal is actually torn or split, as in a fender break, the oxyacetylene blowpipe will quickly make the necessary repairs.

* Publicity Department, Union Carbide and Carbon Corp.

Safe Ending Locomotive Boiler Flues and Super-Heater Tubes

By H. A. WOOFTER*

WHEN a locomotive is in service the flues and tubes oxidize and pit rapidly, due to impurities in the water used, as well as certain other actions due to contraction and expansion of metals when unequally heated. This scouring and pitting action is most violent on the flues and tubes at their junction with the front and rear heads of the boiler, and it is necessary occasionally to remove the flues and tubes from the boiler and "safe end" them. This has to be done in some districts as often as every eight months, while in other sections of the country, where the feed water is purer, the tubes will last from eighteen months to three years without attention.

By cutting off the weakened ends of the flues or tubes and adding a new piece from 8 inches to 12 inches long on one end they can again be reassembled in the boiler and used for another period, when it is again necessary to repeat the same operation. This is known as "safe ending" and applies both to flues and superheater tubes, the new piece added being known as a "safe end."

Until recent years it was the time-honored custom to heat the ends of the old and new pieces in a gas or oil furnace, swage down the end of the old flue, expand the end of the new piece to be added, then force the new end over the old flue in the manner of a scarf joint and hammer the pieces together in a weld by means of a pneumatic hammer. The rejected or imperfect welds sometimes ran as high as 30% on flues welded by the furnace and forge process. Furthermore, the production was limited to a small number of flues per hour for two men.

In 1912 the Norfolk and Western Railroad installed an electric welder for this class of work, followed in a few years by the Nashville, Chattanooga and St. Louis Railroad and a few others. Within the last dozen years more than half of the railroads of the United States and Canada have installed resistance welders in their maintenance departments. Some large roads, such as the New York Central, and the Santa Fe have eight or ten flue welders in their various shops. Customers were urged at first to scarf the ends of the flues and safe ends in a lathe before attempting to make electric welds. Also, they were cautioned to machine the pieces very accurately, so as to obtain practically perfect contact before attempting to weld. But even this order has changed with the advent of better flue welders and now it is found that it is not necessary to scarf the ends of the flues or safe ends, neither is it necessary to do any lathe or machine work, owing to better clamping devices, dies and more uniform distribution of the current to the work. The flues may be either sawed or cut by an ordinary disk cutter or pipe mill. The latest type of flue welder burns off about 1/4 inch from the end of each piece of the work, so that inequalities of surface are in this way eliminated. But it is very essential to have a properly designed, modern welder. Early flue welders were of the butt type only and required nearly a perfect fit between faces of the work.

The present practice, or routine, in the most up-to-date railroad shops is about as follows: The old flues and tubes taken from the locomotives are tumbled or rattled for a number of hours inside a revolving drum, where hot water, steam and sometimes certain chemicals are placed, to remove the rust and scale which has accumulated. The damaged ends are then cut off in a pipe mill or pipe cutter, and they are ready for new safe ends. If, however, the rattler has not completely removed the scale or rust from the ends, or if they have rusted while in storage it is well to have a sand paper belt machine at hand so that they may be pressed against the belt for three or four seconds to clean the end which goes into the electrodes of the welder. The safe ends, ordinarily, do not require cleaning. If, however, they are rusty they also may be cleaned against the sand paper belt. Clean work greatly lengthens the life of the dies, and makes cleaning less frequent.

*Chief Engineer, Federal Machine and Welder Co., Warren, O.

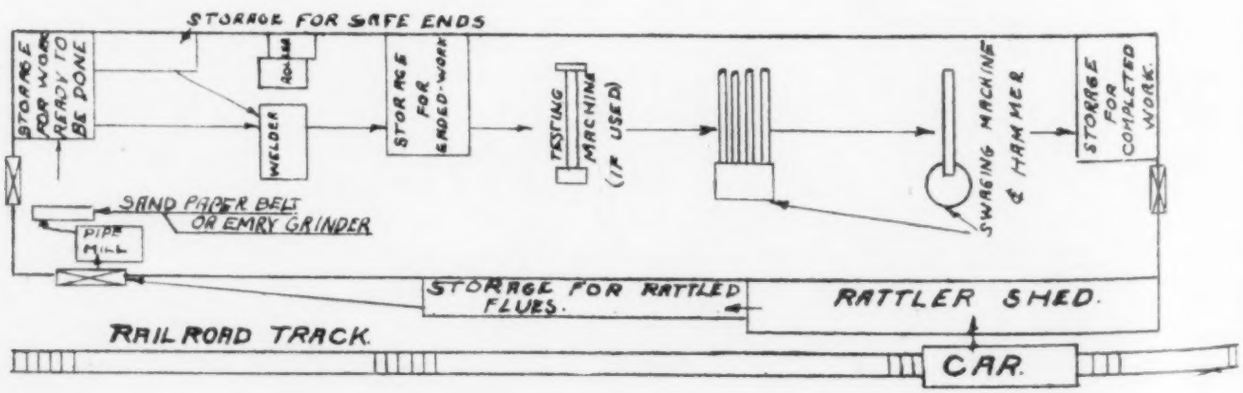


Fig 1—Arrangement of a Flue Welding Shop Using an Electric Welder. Two Welders May Be Used by Making Another Line of Work Down the Other Half of the Same Room. Arrows Indicate Travel of Work to Completion

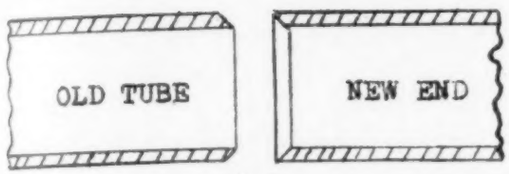


Fig. 2

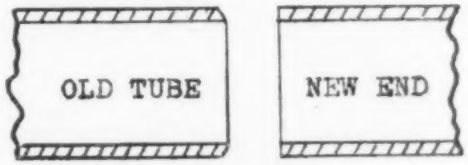


Fig. 3

Obsolete Methods of Repairing Work

The flue and safe end are then clamped in the welder by means of quick acting air cylinders. The weld is made in the period of a few seconds by the flash process. The vicinity of the weld is then heated a little more and mechanical pressure applied so as to make a slight upset, or swelling, in the vicinity of the weld so that it will go over the mandrel. The flue is immediately unclamped, shoved quickly over the mandrel around which three rollers are revolving, which roll down the upset, leaving a smooth surface on both the inside and outside diameters.

The practice formerly was to test each weld, either by means of steam or air pressure, at the same time striking the flue several hard blows with a hammer, and a brush and soapsuds were used to see if any bubbles appeared, indicating leaks. However, a leak was found so rarely that many of the most up-to-date shops do not now test the flues in any manner, but install them directly in the locomotives. Flues are sometimes safe ended by this method as many as ten or twelve successive times.

It is the practice in some cases to weld together pieces of flues or tubing which would otherwise be scrapped, thus making them long enough for a locomotive. This is known as "Reclaiming," or "Salvaging."

The following figures may be helpful.

Figure 1 shows a layout of a modern flue welding room.

Figures 2 and 3 represent what is now an obsolete method of preparing flues and safe ends for the welder.

Figures 4 and 5 show the present practice of preparation, both ends of the work being either sawed or cut in a pipe mill.

It has been found possible to take care of the flues and tubes of from 1000 to 1200 locomotives in one welding machine, by operating it day and night. However, this is not good practice for several reasons, and it is better to have two welders in an average sized shop, one small welder of about 60 to 100 kva. capacity to weld the flues from 2 to 3 inches inclusive, and another larger welder of 200 kva. capacity for welding superheater tubes, the largest of which is usually about $6^1/_2$ inches in diameter. It is possible to take care of all sizes of tubes and flues on one large welder, but it is necessary to change the copper dies to suit the particular diameter of the work.

There has been developed recently the latest and most up-to-date flue welders known to the trade. They are absolutely flash proof, thus insuring long life to the winder and bearings. All moving surfaces slide on hardened and ground steel plates, thus assuring perfect alignment. The clamping device is especially improved over any that has previously been available, assuring long life through its absolute protection from slag, as well as a perfect distribution of current around the circumference of the work.

Two sizes have been developed, the smaller 60 to 100 kva., the larger 150 to 200 kva. These welders can be supplied with either of four different types of pressure devices.

1. Hand toggle which gives the operator perfect control of his work at all times.
2. Hydraulic pressure from an accumulator or pump.
3. An oil gear, or similar device.
4. Hand operated oil jack. (Obsolete)

The oil jack was used on all large early types of flue welders, but is now obsolete. While it is still used in a few shops, it is not recommended. It is too slow in production, and too laborious on the operator. When either the oil gear or accumulator pressure is used, the welder is furnished with a suitable pressure cylinder all ready to pipe up to the pressure device. The smaller welder is practically always supplied with the hand toggle pressure device, since the amount of human energy needed is not great to push up the smaller work. The larger welder should have a mechanical pressure device of some sort, since the large superheater tubes sometimes have an actual cross section of about $4^1/_2$ square inches, requiring about ten tons pressure to push up the weld.

The following Table No. 1, supplied by a superintendent of a railroad shop where an electric flue welder is used, indicates the total cost and production of the electric process over the oil process to say nothing of the enormous saving of time.

Table I

Customer	Process	Size Flue	Production 10 Hours Welded and Rolled	Per cent Defects	Cost per Weld
N. C. & St. L. R. R.	Electric	2 in.	700	0	$00.0104
N. C. & St. L. R. R.	Oil	2 in.	370	30	$00.0354
N. C. & St. L. R. R.	Electric	$5^3/_8$ in.	80	0	$00.0492
N. C. & St. L. R. R.	Oil	$5^3/_8$ in.			$00.14

In the shops where the electric process is used overtime work and work on holidays, Saturday afternoons and Sundays, which require time and a half pay, have often been eliminated, thus making a still greater economy in

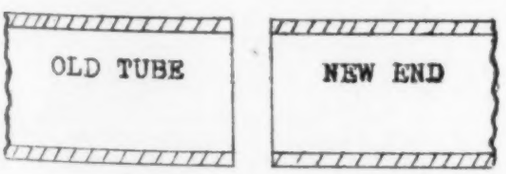


Fig. 4

Ends Sawed Off or Cut in Pipe Mill

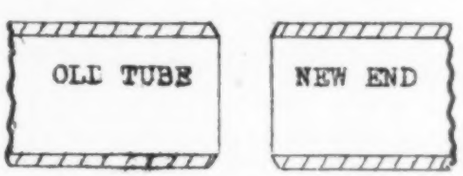


Fig. 5

Ends Cut by Disk Cutter

Latest Method of Preparing Work

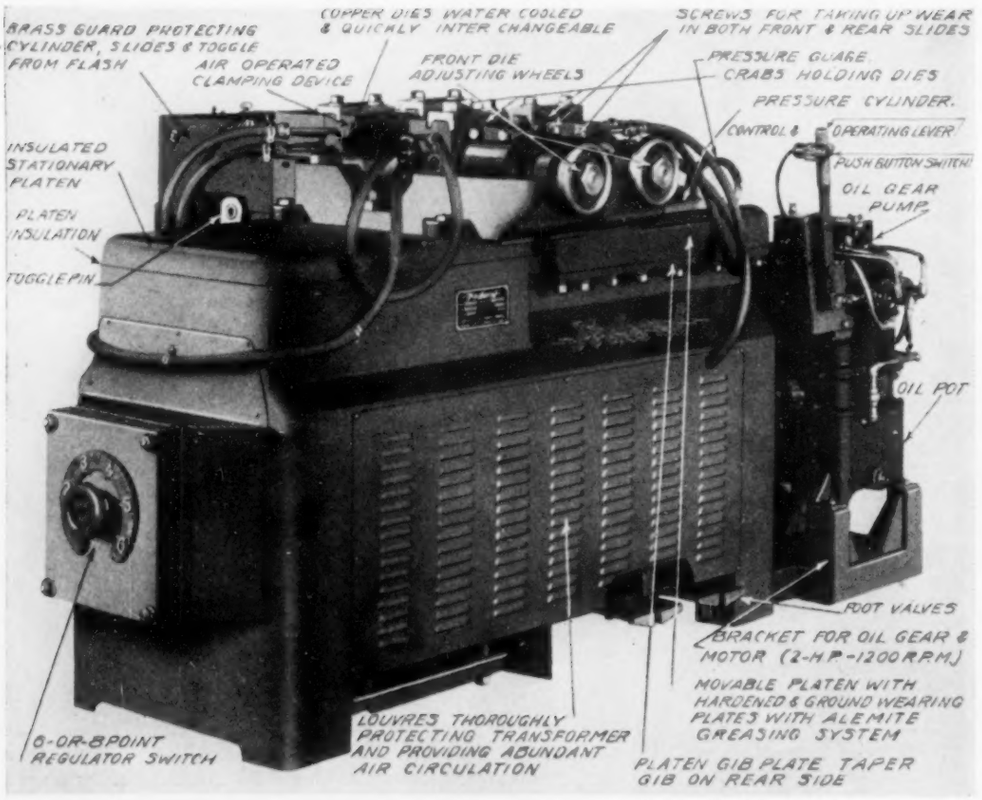

BRASS GUARD PROTECTING CYLINDER, SLIDES & TOGGLE FROM FLASH
COPPER DIES WATER COOLED & QUICKLY INTER CHANGEABLE
AIR OPERATED CLAMPING DEVICE
FRONT DIE ADJUSTING WHEELS
SCREWS FOR TAKING UP WEAR IN BOTH FRONT & REAR SLIDES
PRESSURE GUARD
CRABS HOLDING DIES
PRESSURE CYLINDER.
CONTROL & OPERATING LEVER
PUSH BUTTON SWITCH
OIL GEAR PUMP
INSULATED STATIONARY PLATEN
PLATEN INSULATION
TOGGLE PIN
OIL POT
FOOT VALVES
BRACKET FOR OIL GEAR & MOTOR (2-H.P.-1200 R.P.M.)
MOVABLE PLATEN WITH HARDENED & GROUND WEARING PLATES WITH ALEMITE GREASING SYSTEM
6-OR-8 POINT REGULATOR SWITCH
LOUVRES THOROUGHLY PROTECTING TRANSFORMER AND PROVIDING ABUNDANT AIR CIRCULATION
PLATEN GIB PLATE TAPER GIB ON REAR SIDE

Fig. 6—Flue and Tube Welder—Capacity 2" to 6⅛" O.D. with Hydraulic Pressure Device and Air-Operated Clamps

the boiler department of the shop. When the welder is not being used for flues or tubes, by inserting suitable dies it can be used for welding round or bar stock, or for annealing, or for heating and stretching, etc. By the use of special dies the flue welder is often used to weld the return bends to superheater pipes, thus making an additional saving of time and money. One weld at a time is made on the small welders, but two welds at once are made on the larger welders. The welded joints in return bends have an enormous factor of safety over the obsolete threaded joints. It is sometimes remarkable to note the novel and unusual uses that customers make of electric welders. In one shop visited by the writer two men getting a production of from 80 to 100 welded $5^{3}/_{8}$ inches diameter superheater tubes per day, whereas they had considered themselves fortunate to secure twenty welds per day by means of the oil forge.

Table 2 indicates the approximate cost for the electric power only which is required for certain diameter flues and tubes.

Table 2

Size of Flue	Time in Seconds (Welding Only)	Production in 9 Hours Welded and Rolled	Cost per 1000 Welds at 1¢ per Kwh.
2 in.	About 4 to 7	700	$1.25
3 in.	About 5 to 8	500	1.75
4 in.	About 20	250	3.00
$5^{3}/_{8}$ in.	About 30	75	5.00

Tables 1 and 2 were compiled about fifteen years ago, and were based on welders that are now obsolete, and power rates that were higher than at the present time. Tabulations based on the latest types of welders would show much greater production, and greater reduction in cost of operation. It is conservative to estimate that the electric process of safe ending costs only one-third as much as the oil process.

For rolling down the welds of safe ends the "Hartz" roller has been found fairly satisfactory and it is usually installed at the left-hand end of the welder so that the work may be quickly unclamped and shoved endwise over the mandrel between the rollers, while still in practically a plastic condition. The time required to roll down a weld is about two seconds on this type of roller. But the "Hartz" Roller is limited to welds that are 14 inches or less from the end of the work. For "Reclaiming" or "Salvaging" where the welds may be anywhere from 2 ft. to 6 or 8 ft. in from the end of the work, a special type of roller with about a 9-ft. throat is necessary. This special roller will also roll down the welds in safe ends. Hence, it is preferable to install the special roller only so as to give the welder its fullest range of usefulness. This rolling device should always be installed at the left hand end of the welder in line, longitudinally, with the dies, so that the hot work can be shoved endwise to the left, over the mandrel, and between the rollers, the instant it is unclamped. Some shops using "Hartz Rollers" prefer to install them parallel to, and about four feet from the welder, and directly back of the operator. This is not the best practice, however, for the work must be taken entirely out of the welder, and the operator must turn around in order to get the work into the roller and out again, with considerable loss of time and reduced production.

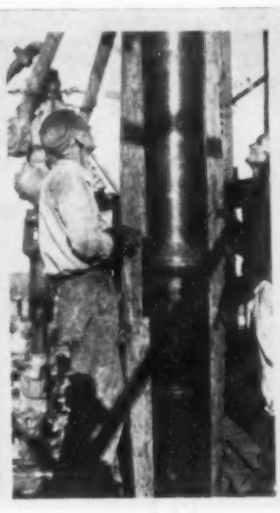
The best method of cleaning the ends of flues and tubes is by means of a sand paper belt running over two pulleys, similar to a band saw. There are several makes on the market, any one of which will give satisfactory results.

About twelve years ago a prominent railroad company made up a test flue by welding together ten pieces of 2 inch diameter by 8 inch long boiler flues. This sample flue was then bent cold around a 20-inch diameter mandrel and then subjected to a water pressure test. There were no leaks or creasing or buckling. It shows conclusively that the welds are at least 100% as strong as the original flue, but are most likely about 110% as strong, due to the pressure of the rolling having refined the grain of the metal at and near the weld.

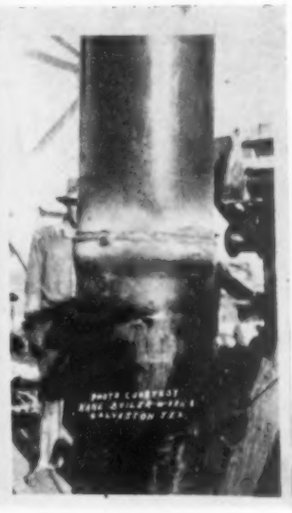
The Electric Flue Welder is widely used in pipe and tube mills. In one factory visited by the writer 2 inch diameter standard pipe was being welded together into continuous straight pieces, each half a mile long. As the pieces were being added to by welding it was necessary to run them out through a long field. They were brought back by being wound into large spiral coils, ten feet high for heating coils and refrigerating tanks. In the same plant several welders were being used to weld together sections of loop coils, for heating systems.

Picking Up Casing Joint with Elevators

Stabbing Casing



Aligning Casing Before Welding



Completed Weld, 18⅝" Casing

Casing Pipe Welding

By H. S. CARD*

IN the production division of the petroleum industry the welding of oil well casing pipe seems destined to become an accepted standard operation. Yet in spite of the advantages which are offered by a satisfactory job there are numerous special problems involved which differentiate this application from the many pipe welding jobs that have been completely approved. Some of these problems affect the welder only indirectly. One of these is the fire hazard when gas is present. This was a source of worry at the beginning but it was found to be adequately controlled by the use of heavy mud. In rotary drilling the weight of the mud can be controlled, and as a hole is kept full of mud at all times operators are able to control the gas, except in a very few fields. These more hazardous fields are known and welding is not attempted in them. However, the same hazard exists in other methods of running casings, because sparks may be thrown off by threaded and coupled pipe and by tools inside the casing. Another problem arises from the fact that deep well casing pipe is frequently made of medium carbon steel of high-tensile strength and the high-carbon content of the material makes necessary special procedures which slow up the work, and time is precious in oil well work. However, if other difficulties are overcome, which appears to be a certainty, it is probable that casings of more easily weldable quality will be made available without undue sacrifice of strength.

It should be obvious that a considerable portion of the advantage gained by using the higher carbon steels is lost by the reduced efficiency of the pipe wall where threads are cut, and this could be more than offset by using material which would permit of developing 100% efficiency at the joint. Success in this field will therefore depend on perfecting operating methods that insure gas tight joints at a speed comparable to running a string of coupled joints.

Electric arc welding has the preference of most contractors, because of the greater ease of making a double bead weld, and of minimizing the heating of the parent metal. The arc weld suffers less quenching effect when the finished joint is lowered into the well, and that is of great importance to the contractor, who wants to go down with the casing without loss even of seconds.

Oil men are interested in two qualities that are inherent in good pipe weld. One is that having been made leakproof it stays leakproof because there is nothing about it that can work loose. Another is that it can be made permanently as strong as the pipe itself.

* National Electrical Manufacturers Association.

The welding problem, then, is to do a 100% job and do it fast. Some of the earliest welded strings took as much as three times the running time as equivalent coupled strings but that time differential has been almost completely removed, and after a little more experience has been gained there will be no question as to the speed of running arc-welded string.

Much interest has naturally centered in the subject of joint design. In general the choice is between a butt joint and some form of the bell and spigot type of pipe joint, and both types are being used. Kane Boiler Works, of Galveston, Texas, has been working on this problem for over fifteen years, starting with large diameter pit casing for water wells and following down through the small diameter ($5^1/_2$ inches) casing used for the mile-deep oil wells of the present day. This company has patented a bell and spigot type of joint which has an inside bevel on the lip of the bell. The claim made for this design is that full penetration through the root of the weld is obtained on the first bead, which is refined in its structure by the second, or sealing, bead. There is, of course, no chance for weld metal to protrude into the pipe, so high heats can be used, which in turn helps to reduce the welding time required. Records of some 200 strings of casings recently run by this company in sizes from $5^1/_2$ inches to 16 inches in diameter, and totaling well over forty miles, show that the time has compared very favorably with that of coupled joints, and that the casing cost has often been appreciably lowered. Over six hundred strings of oil well casing have been run to date, averaging some 1600 feet in length. The average length of string is increasing because they are now running some strings of over 6500 feet and will very shortly run some 7500 feet string. Faster work can be done when circumstances warrant the increased cost of equipment and overhead for doubling the number of welds made at one time.

Continued study of the mechanical problems and welding problems involved will undoubtedly lead to reduced costs and better welded casings. The amount of welding involved is considerably greater than in the case of overland pipe lines. In 1936 there were over 20,000 oil and gas wells drilled and cased at an average depth of about 4000 feet. Continued drilling activity, taking into account the trend toward deeper wells, could easily develop a welding volume equivalent to 15,000 to 20,000 miles of casing pipe annually.

Plate Crumples But Welds Hold

By H. S. CARD*

THE accompanying photographs are not intended to show how a properly welded tank should look, but they do show how it will act under certain conditions, and by acting that way this tank put its welded seams through a severe test. Built by Wyatt Metal and Boiler Works, Houston, Texas, for petroleum storage, the tank holds 15,000 barrels, measures 55 feet in diameter by 35 feet 7 inches high. Plate thicknesses used were as follows:

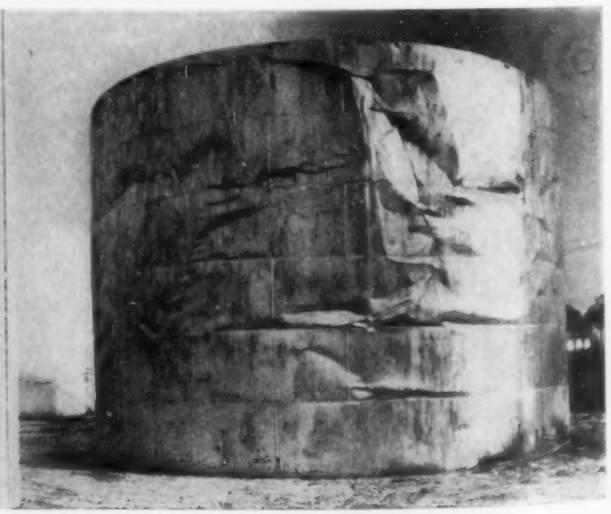
Bottom	$^1/_4$ inch
First ring	$^1/_4$ "
Second ring	$^7/_{32}$ "
3, 4, 5, 6 ring	$^3/_{16}$ "
Roof	$^3/_{16}$ "

Bottom angle 3 x 3 x $^5/_{16}$ in.

In the shell of the tank lap joints were used throughout, the vertical seams being 100% welded on both sides, and the horizontal seams 100% welded on the outside and seal welded on the inside.

The crumpling of this shell was not caused by a shower of box cars as the picture might indicate. What happened was that a cold rain fell on it suddenly while it was being cleaned out with live steam, causing a vacuum which sucked in the plate. The second illustration shows how it looked after it had been forced back by water pressure. Some of the dents had to be pulled out mechanically, small pads being welded to the shell to give the necessary "hold." The high quality of the welding workmanship is shown by the remarkable report that no damage was done to any of the welds, although the parent metal split in several places and had to be repaired by welding.

* National Electrical Manufacturers Association, Electric Welding Section.



Welded Ships

By A. F. DAVIS*

LAUNCHED June 5th at the River Rouge, Michigan yard of the Great Lakes Engineering Works was the second of unique arc-welded twin 300-ft. ships largest ever built in a Great Lakes shipyard without rivets. The three illustrations show, respectively, the vessel ready for launching, Fig. 1; being launched, Fig. 2; and launched, Fig. 3. For operation on the Great Lakes and through the New York State barge canal to Atlantic coast ports, this craft and her sister ship can carry 300 tons more cargo than the same size vessel riveted.

Fig. 1—Ready for Launching Fig. 2—Being Launched Fig. 3—Launched

The vessel is 300 ft. long, 43 ft. beam and 20 ft. deep. The design for arc-welded construction was the work of Gielow, Inc., New York City, naval architects and marine engineers in conjunction with the shipyard. The vessel is transversely framed to comply with the rules of American Bureau of Shipping. Power will be supplied by two eight cylinder, four cycle, six hundred horsepower Bessemer Corporation diesel engines driving twin screw propellers.

The use of electric welding in construction permitted fabrication of the hull in complete sections in the shop. An advantage of electric welded ship construction, this method permits fast assembly and considerable economy. According to the builder, the total man hours in construction of a welded hull is less than where riveting is used.

Construction of the vessel has been followed with a great deal of interest.

America's Cup Defender "Ranger" Utilizes New Method of Steel Construction

THE racing yacht "Ranger," (see Fig. 4), which recently successfully defended the America's Cup, embodies latest advanced principles of yacht design and construction. "Ranger" was designed by W. Starling Burgess, designer of last year's America's Cup winner "Rainbow," as well as the previous "Enterprise." Mr. Burgess' father, before him, designed three America's Cup winners. Bath Iron Works, Bath, Maine, builder of many America's Cup boats, built "Ranger." She is all-steel construction and utilizes shielded arc welding extensively.

"Ranger" is 135 feet 5¼ inches long over-all, 87 feet at the waterline, 21 feet maximum beam and 15 feet draft. Her mast, 165 feet long, (seeming to touch the clouds in Fig. 5), 22 inches by 14 inches at the base, 11 inches by 7 inches at the top, will carry between 6000 and 7000 square feet of main sail. To obtain the strength required to withstand the terrific stresses of this tremendous sail area, and to keep weight at a minimum, the mast was fabricated of duralumin and the fittings were welded by the electric-arc process. To counter-balance the draw of her mammoth sails, "Ranger" has a lead keel weighing 110 tons, heaviest ever used on an America's Cup boat. This tremendous weight is held in place by a flat keel plate of arc-welded steel to give the required strength without extra weight. The stresses to which the mast and keel plate are subjected when the "Ranger" is underway with all sails drawing are terrific. The force applied by wind against the huge sails tends to push

*Secretary, The James F. Lincoln Arc Welding Foundation.

Fig. 4—"Stepping" the 165-Foot, Duralumin Mast of the America's Cup Defender, "Ranger," Built at Bath Iron Works, Bath, Maine, for Harold S. Vanderbilt

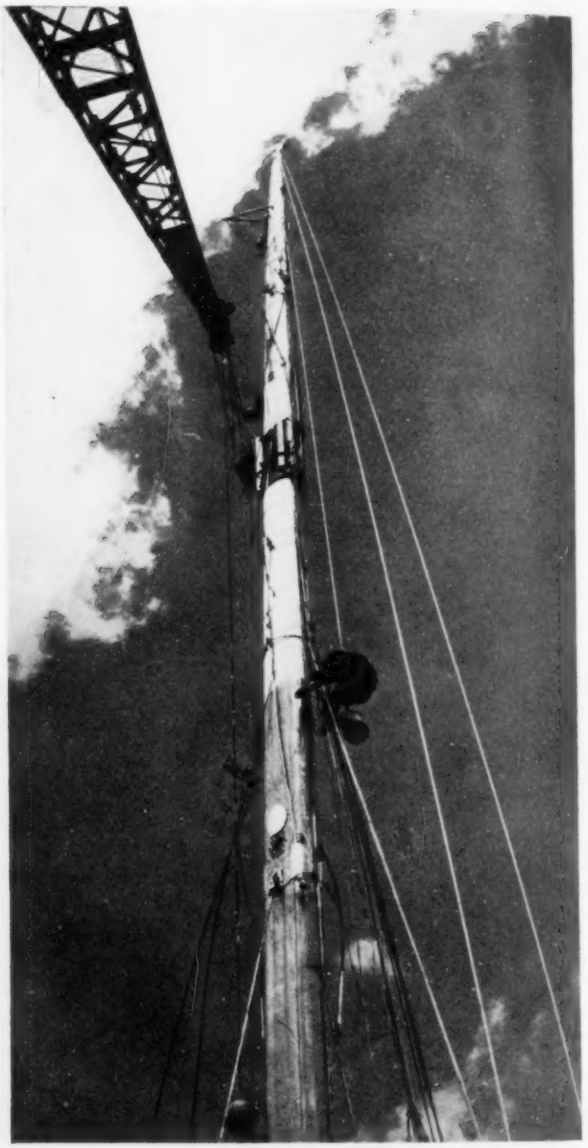


Fig. 5—Painting the "Ranger's" 165-Foot, Duralumin Mast Which Seems to Touch the Clouds (Upper Right)

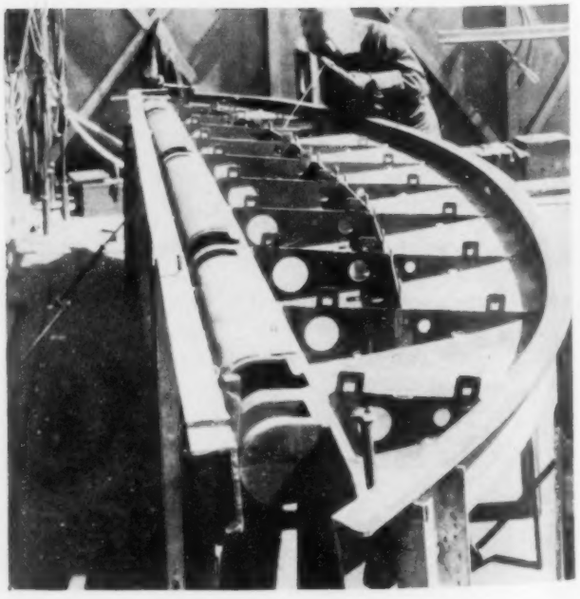


Fig. 6—"Ranger's" Rudder 13 Feet Long, 4 Feet Wide Built of Arc-Welded Steel for Utmost Strength at Least Weight (Lower Right)

the mast one way. The 110-ton keel, pulled downward by gravitation, pushes the opposite way.

In addition to mast and keel plate, the "Ranger's" stem, her rudder and stern frame are arc welded for greatest strength per pound of weight. The stem is fabricated of three plates, 48 feet long, $4^1/_2$ inches wide and $^5/_8$ inch thick. Use of electric welding in construction made it possible to fabricate the stem to conform exactly to the lines of the hull. In previous boats, the stem had been cast to an exact pattern. With welding it was not only possible to obtain great exactness but the structure was considerably lighter yet much greater in strength.

"Ranger's" rudder (see Fig. 6), another part of her structure which must resist extreme stresses, is entirely weld-fabricated. It is 13 feet in length and 4 feet in maximum width. The construction is evident from the illustration. It consists of various steel shapes and plate cut to conform to designed size and form, then fused into a single unit by the electric arc.

The "Ranger's" stern frame was fabricated entirely from flat steel plates arc welded together.

Repairing Casting

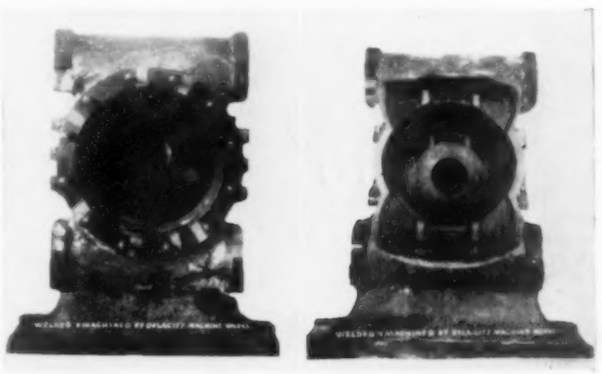
By M. G. MOSSHOLDER*

THIS casting illustrated is a 20 x 20 inch Steam Corliss engine cylinder. The piston rod broke at the crosshead, and the piston came out at the end of the cylinder. The end was broken into eight pieces, and the break extended up into the steam port, and down into the exhaust port.

The first step was to weld the eight pieces together. Some idea of the size of these welds may be shown by the fact that they required an average of one cylinder of oxygen each. After the pieces were assembled, the cutting edges of the steam and exhaust ports were built up, so that when they were bored they would be standard size. All of the above described welds were made with cast iron.

After all of this was accomplished the one large piece was tack-welded to the cylinder, and local preheating applied, and the end bronze-welded on, requiring slightly over one hundred pounds of bronze.

On cooling, the cyclinder was refaced, drilled and tapped for studs, counter bore rebored and valve ports cross bored.



This engine was back in service within two weeks, and is working its third year resulting in a saving of two-thirds the cost of a new cylinder, on which delivery could not have been made in less than ninety days.

This is one of over one hundred and fifty steam, gas, diesel and compressor cylinders that we have welded and put back in service, with 100% results.

*Oklahoma City Machine Works.

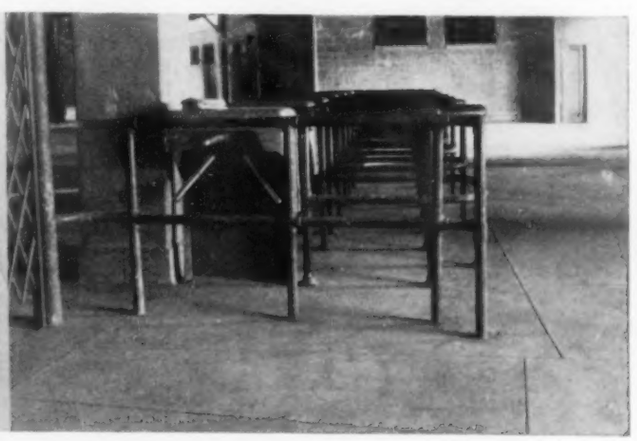
Jersey Muncipal Stadium

By HUGH C. CLARK*

Welding (gas and arc) has been used extensively on the Jersey City Municipal Stadium.

Welding was used on all pipe rails, all window bucks, miscellaneous structural iron work, construction of window guards, and in numerous other instances.

* City Development Engineer.



New German Bridges*

By Dr. ING. G. SCHAPER†

Welding

THE successful results obtained through the adoption of welding practice in mechanical engineering, rolling stock construction and shipbuilding gave rise to the question, some ten years ago, whether technical and economic advantages might not also be obtainable by this means in bridge work. After exhaustive preliminary experiments and theoretical investigation, the first all-welded railway bridge was completed in 1930, a structure having plate-webbed main girders of 10 m. (32.8 ft.) span. The bridge was first incorporated in a track that was not under regular traffic and was there subjected both to heavy loading by locomotives standing on it and crossing it at high speed, and to heavy dynamic stresses in rapid sequence produced by a vibrating machine. Having shown an excellent performance in these tests the bridge was then transferred to a main line carrying heavy express traffic.

The material used for the superstructure of this bridge was St 37, and it was welded with bare electrodes. The

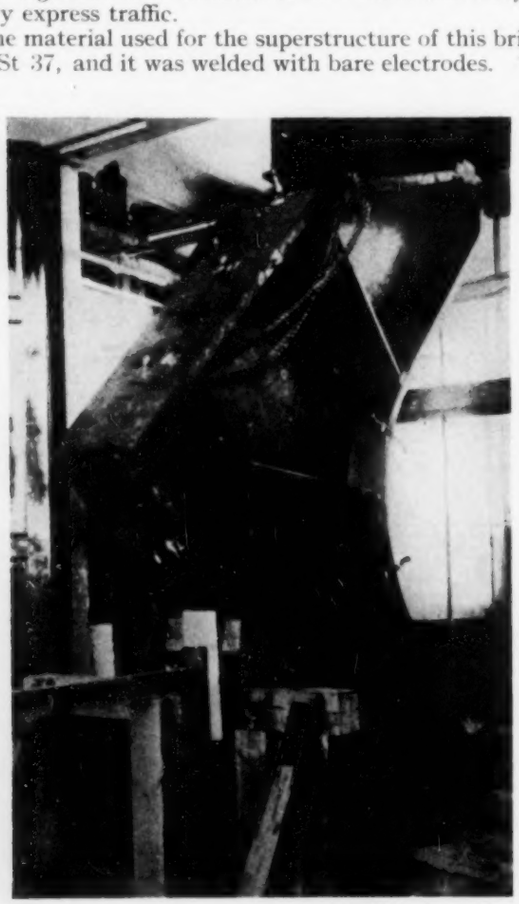


Fig. 1

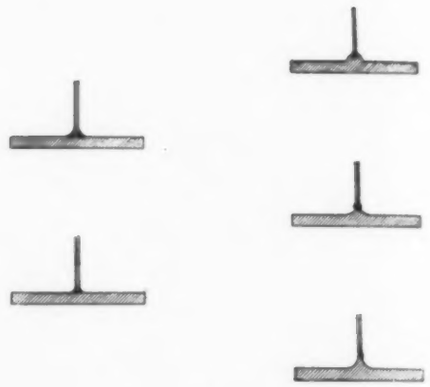


Fig. 2

cross girders were connected to the rail bearers, and the main girders to the cross girders, by means of strong, rough transverse fillet welds, and the curtailed ends of the outer flange plates were treated in the same way; an arrangement which would nowadays be avoided on principle, because of the notch effect which is strongly detrimental to fatigue resistance. The span has, however, been in service for more than six years, and in this period has been crossed by some 230,000 trains, subjecting the longitudinal girders and cross girders to the loading of more than one million heavy locomotive axles in addition to more than ten million lighter axles of rolling stock. The bridge has now been taken out of service for the purpose of detailed investigation. Up to the present no defect has been found in it by eye or with the magnifying glass; it is to be subjected to laboratory tests by radiography and measurements of electrical flow, and to fatigue experiments, extending to every detail and to every possible kind of defect.

Since this first welded railway bridge was built extensive fatigue tests have been carried out on welded connections and on completely welded girders, and as the result of these our knowledge of the correct design of welded bridge work has been so enlarged that even bridges of wide span can now be constructed in this way with perfect safety. There are, in fact, already 150 welded railway bridges with plate-webbed main girders in service on the Reichsbahn, the maximum span being 54 m. (177.2 ft.). A further number of bridges of this type have been constructed for the Reichsautobahnen (special motor roads) with spans up to 103 m. (337.9 ft.).

In Germany, up to the present, the only welded railway and roadway bridges have been solid webbed girders. The use of welding in the construction of trussed railway bridges is still exposed to challenge as the question of how to ensure perfect connections at the intersection points, possessing the requisite high degree of fatigue resistance, has not yet been cleared up. Trussed bridges for highways can, however, now safely be built by means of welding, as in these the consideration of fatigue effects is of minor importance.

---

* Extracts from paper read at a joint meeting of the Institution of Structural Engineers and the Institution of Civil Engineers at the Institution of Civil Engineers, Great George Street, London, S. W. 1, on Thursday, March 18, 1937.

† Director of the German State Railways.

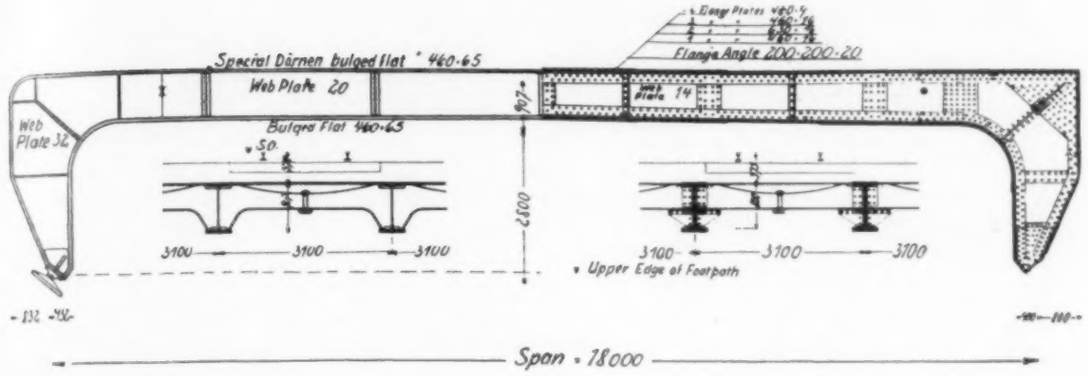


Fig. 3

Shrinkage Stresses

The welding of plate web girders entails the development of considerable shrinkage stresses in the longitudinal seams connecting the flanges to the web, amounting to as much as 2000 kg. per sq. cm. (28,500 lb. per sq. in.), and many engineers have feared that these high stresses in augmentation of the ordinary dead load and live load stresses were bound to lead to the early failure of the girder. In entertaining these qualms, however, they had overlooked the fact that rolled joists likewise acquire very heavy residual stresses from the rolling process but, nevertheless, carry as heavy loads as girders which are free from all internal stress. It has, moreover, been conclusively demonstrated by means of numerous tests that welded plate web girders possess greater fatigue resistance than riveted girders.

Shrinkage stresses, then, are not a source of danger, and they play no part in determining the load bearing capacity of a girder. One reason for this is that heavily stressed parts are surrounded by parts carrying much lighter stresses, but a more fundamental reason is that the shrinkage stresses from closed systems which are in equilibrium on their own account and which are *not* superimposed on the normal dead load and live load stresses of the structure.

In welded portal frames the shrinkage stresses resulting from the welding of the web plates at the corners attain values of the order of 2000 to 2600 kg. per sq. cm. (28,500 to 37,000 lb. per sq. in.). Figure 1 shows the set-up of an experiment in which a full sized corner of such a frame was placed in a compression testing machine and was loaded to produce stresses of 2500 kg. per sq. cm. (35,600 lb. per sq. in.) which had then in fact been superimposed on the shrinkage stresses, must inevitably have led to failure before attaining even half that value; yet the structure showed not the slightest sign of disturbance under these stresses, which were the heaviest that could be obtained in the available machine. The material in question was St 37. The experiment confirms that shrinkage stresses are not dangerous.

It has further been ascertained by means of fatigue tests that joints in the web and flange plates of solid webbed girders are most effectively made in the form of simple butt welds, double-V, V- or U-shaped in cross section. The joints are not improved by the addition of cover straps. It is essential, of course, that the seams

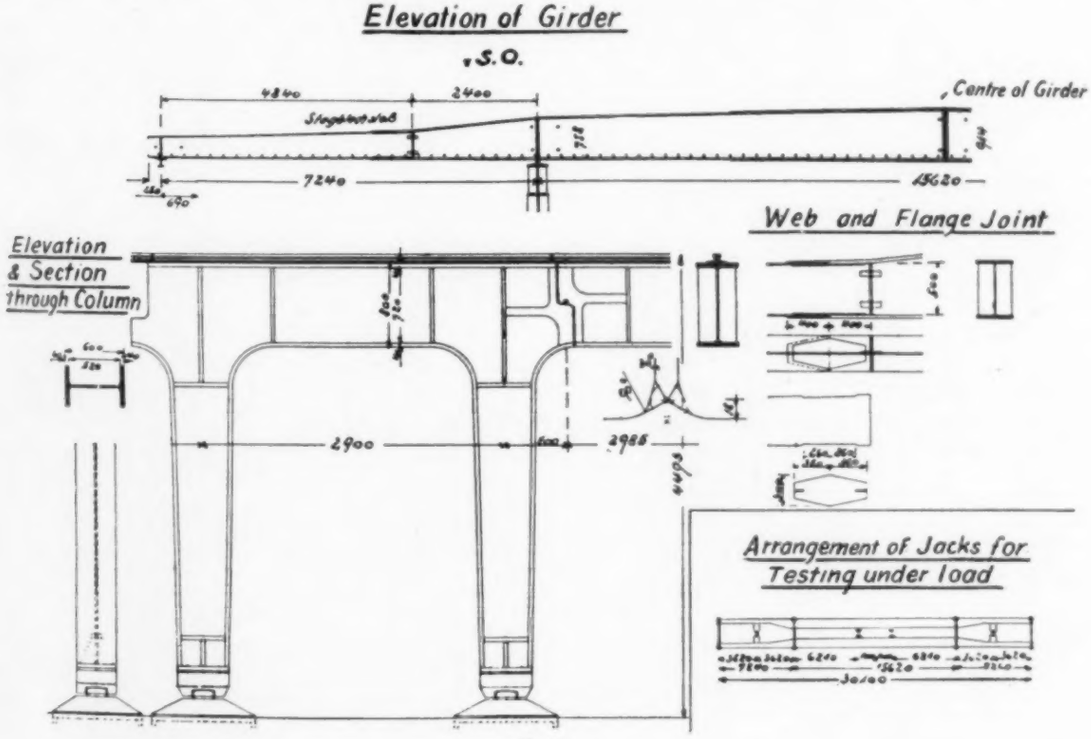


Fig. 4

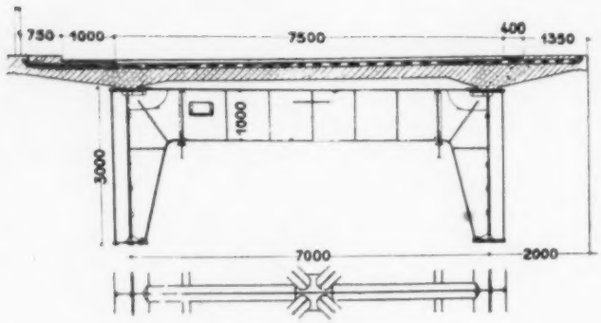


Fig. 5

should be completely free from defects, and that there should be no incipient cracks in the successive runs of weld metal. The freedom of the butt welds from defects must be checked by X-ray photographs. It is best to form the butt joints in the flanges at an angle of 45° to the longitudinal axis of the girder as they will then possess considerably greater fatigue resistance than if arranged at right angles. The transitions between the butt welds and the parent material should be milled or ground to combat the notching effect, as in this way the fatigue resistance of the connection is greatly increased.

It may, then, be taken as proved that shrinkage stresses are not a source of danger in the girders themselves. Suitable precautions may, however, be taken when making the butt welds in the joints of the longitudinal girders, cross girders and wind bracings to ensure that such stresses shall be kept down to a minimum. With this object in view the procedure followed in assembling the deck of the bridge is as follows: first, a single cross girder is welded to the two main girders at the center of the span; then this is welded to the ends of the rail bearers in the spaces on either side of it, and the far ends of these are welded to the cross girders next in order on either side of the center; next, these cross girders which have hitherto been loose are welded to the main girders, care being taken to stress them in opposition to the shrinkage stresses during the process. This sequence is repeated, working from the center toward both ends of the bridge, until the last cross girder but one has been connected near each end. The endmost cross girders of all must then be welded into place accurately at the points provided for them, and the rail bearers in the end spaces are cut accurately to length on the side and are finally welded into position (between the last cross girder and the last but one) after this has been done. If this procedure is followed the shrinkage stresses arising in the connecting seams of the rail bearers are limited to very small amounts.

Flanges for Plate Girders

The types of flange construction used in welded plate webbed girders are represented in Fig. 2, namely:

An ordinary flat rolled plate welded to the ordinary square edge of the web plate.

An ordinary flat rolled plate welded to a double-bevelled (V-shaped) edge on the web plate.

A "nosed section" rolled with a protrusion, along the center line and a groove, to receive the web plate, in the middle of the protrusion.

A "bulged section" having a central triangular protrusion which is welded to the web plate by two V-seams.

A special form of T-section allowing the connection to the web plate to be made by a single V-seam.

Where ordinary flat plates are used it is not possible to examine the seams connecting the web to the flange by means of X-rays, but using the other kinds of section this is readily accomplished.

Welding Aids

The simplest and most reliable welding is done with the seams in a horizontal position and with the center line of the cross section of the seam vertical. To enable this the girder about to be welded is supported between plate-webbed circular sheaves fitted with rims whereon it can be rolled to bring each of the various seams into the proper position. Where the flanges consist of ordinary flat plates the connecting seams between these and the web plate are welded with the girder in an inclined position. The sheaves may be arranged either to roll forward and back on horizontal runners laid on the ground, or, against fixed rollers. On many constructional sites it is impossible to make use of any turning mechanism, and vertical or even overhead welds may have to be carried out, such as are usually necessary in the course of erecting the decking of the bridge. If skilled and experienced welders are employed such work can be done with entire freedom from defects.

Advantages of Welding

The main points that weigh in favor of the adoption of welding are as follows:

(1) Welded structures are considerably lighter than riveted because, in the case of members subject to tension, no addition has to be made to the cross section of a member to compensate for its reduction by rivet holes, and also because members meeting at 90° or at any other angle can be connected directly by weld seams without the necessity for angle cleats as in riveted work. As a result welded structures are up to 23 per cent lighter in weight than their riveted equivalents. Moreover, it is possible for a well equipped and experienced steel fab-

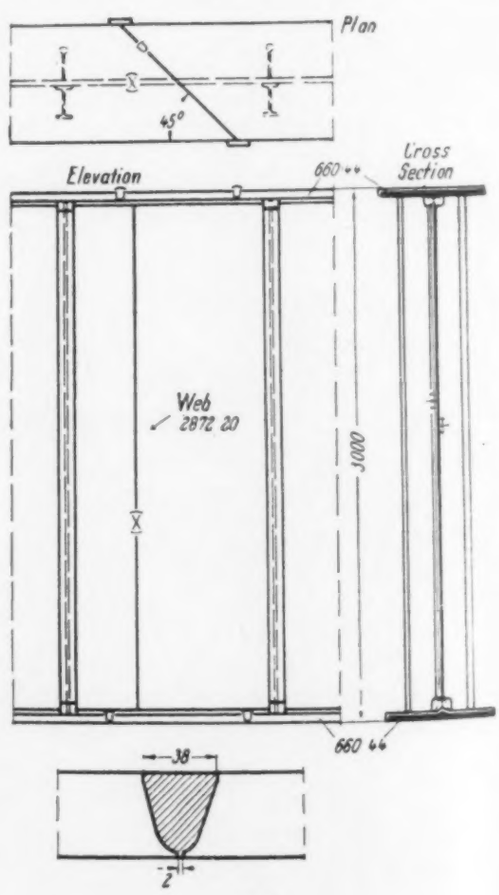


Fig. 6

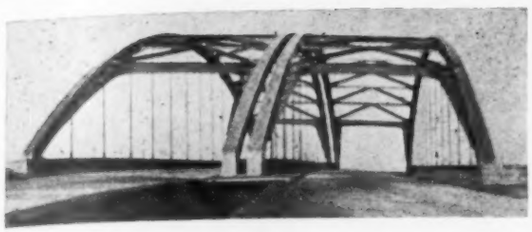


Fig. 7

ricating shop to turn out welded structures at a sufficiently low cost per ton to turn the saving in weight into an over-all saving in cost, and this despite the greater care needed in welded work, the high prices charged for good welding rods, and the cost of subjecting important seams to X-ray examination.

(2) In the case of road bridges decked with a reinforced concrete roadway slab which is to be supported either on the upper flanges of the main girders or on those of intermediate longitudinal girders, or on both, the use of welding enables such support to take the form of direct contact. With riveted girders this would be quite out of the question as it would prevent the essential provision being made for the replacement of loose rivets in service.

(3) There are many instances where frames, portals and stanchions to carry heavy loads cannot be constructed at all except by the use of welding.

(4) Apart from the technical and economic advantages of welding in bridge construction it is to be preferred on account of the pleasing appearance obtainable. The disposition of surfaces on the main girders of a bridge of welded construction is æsthetically excellent and the appearance is far better than that of a riveted main girder. In large riveted girders additional flange plates have to be provided above the upper flange and underneath the lower flange, and these, together with the arrangement of flange joints, produce a stepped elevation which is lacking in repose. In the case of welded girders, however, butt joints may be used and the additional flange plates where necessary may be placed underneath the upper flange and above the lower flange, to that the outer surfaces are left perfectly straight.

(5) In skew bridges it is often desired for architectural reasons to arrange the cross girders parallel to the abutments. By the use of welding the necessary skew connections between the cross girders and the main girders can be arranged in the simplest manner possible whereas with riveted work their design leaves much to be desired both technically and æsthetically.

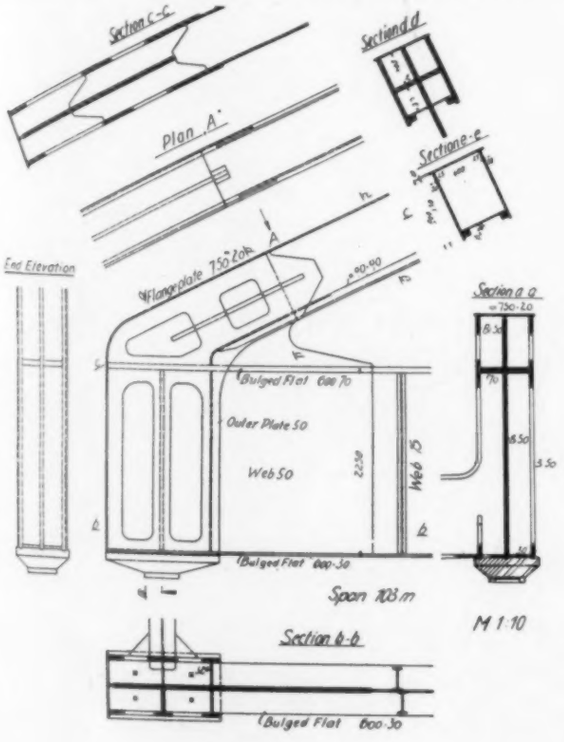


Fig. 8

Welded Rigid Frames

Some examples will not be given of plate-webbed rigid frame girders. Figure 3 shows such a structure of 18 m.

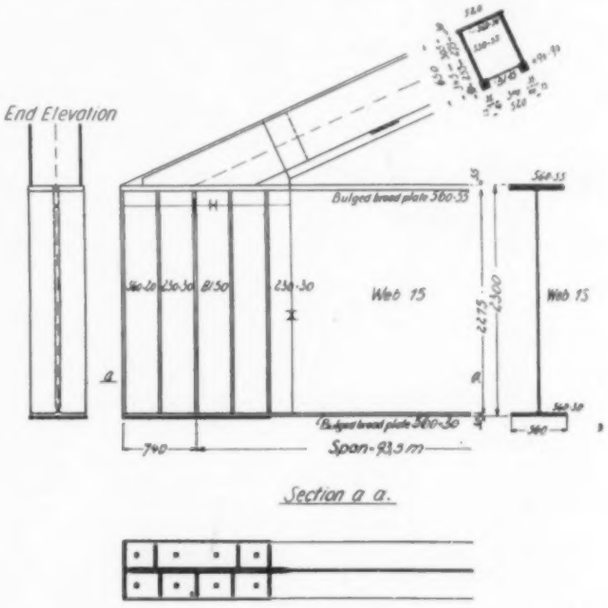


Fig. 9

(59.1 ft.) span built over a passenger subway in Duisburg station. This subway was constructed in a number of sections independently at considerable intervals of time, the riveted design shown in the right hand half of the illustration being adopted in the earlier work and the welded design appearing on the right in the sections built later. The welded frames are 26 per cent lighter than the riveted.

Figure 4 indicates the design of a bridge over a street all of welded construction and intended to be encased in concrete. The side openings are spanned by two-hinged portal frames which also serve to carry hinges for the end bearings of girders over the central opening. These hinges are steel castings welded to the web plates as illustrated.

Figure 5 shows the construction of the Reichsautobahn viaduct near Kalkberge in the vicinity of Berlin, crossing a flat valley, 740 m. (2427.8 ft.) in width, by 13 spans. Each of the two carriage-ways is separately supported on two plate webbed girders of uniform depth, at 7 m. (23.0 ft.) centers, and the spans are respectively four of 47 m. (154.2 ft.) and nine of 61.2 m. (200.8 ft.). The cross girdering is in the form of portal frames, and the reinforced concrete decking slab rests directly on this and on the main girders. The whole of the superstructure is of St 52 and is welded (Fig. 6), with which object the flanges of the main girders are in the form of "bulged sections" (see Fig. 2); site joints in these and in the web plates are arranged to occur in approximately the same positions, corresponding to the points of inflection, and

are plain butt joints without cover straps—U seams in the case of the flanges and double-V seams in the web plates. The flange joints are placed diagonally at 45°. The girders were erected on fixed scaffolding and the welding had, therefore, to be carried out in a vertical position, the procedure at the site being as follows:

First, five runs of weld metal were deposited in both flange joints simultaneously. Then one side of the double-V seam forming the web joint was deposited by intermittent welding upward and downward from the middle, and at the same time welding was continued in both the flange joints. As soon as the double-V joint in the web plate had been completed on one side, intermittent welding was carried out in the same way from the other side, working upward and downward. The timing and sequence of the various welds were so planned as to ensure that all three seams should be completed at the same time. The main girders were supported on rollers while the joints in them were being welded, in order to enable them to follow the shrinkage occurring in the seams, and the rolling friction was overcome by the use of light tackle.

The piers under the bridge are of concrete faced with yellow stone, and in order to obtain an effect of pleasing lightness they are pierced by an arched opening under the center of each of the carriage-ways.

Near Duisburg the Reichsautobahn crosses over the railway yard where it was not possible to allow intermediate supports between the tracks, so necessitating a single span of 103 m. (337.9 ft.); considerations of head-

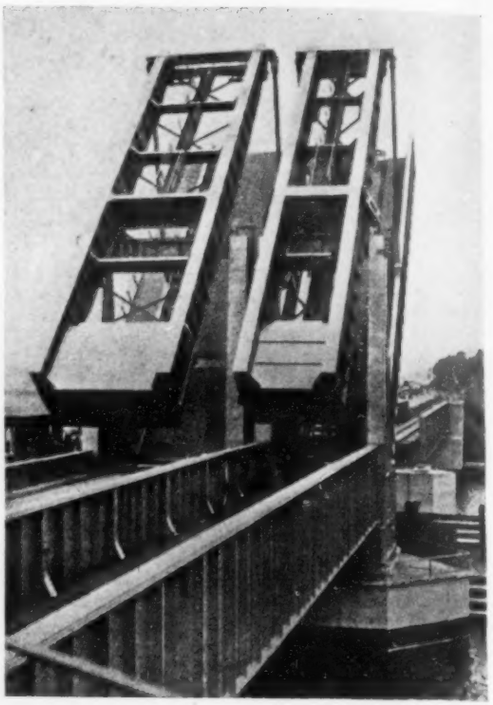


Fig. 11

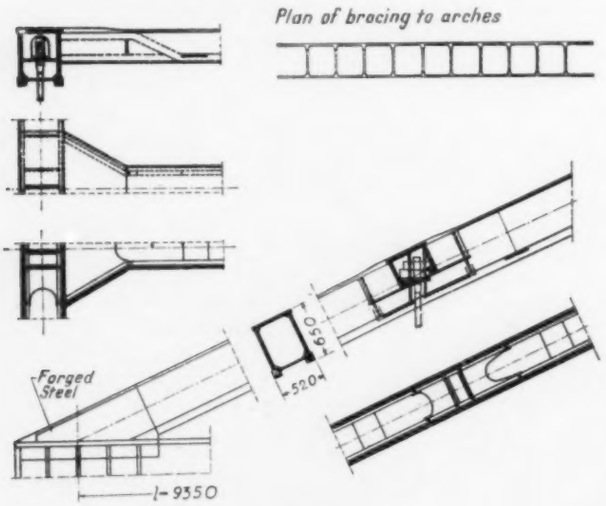


Fig. 10

room, moreover, made it necessary to select a form of bridge with the main girders above the level of the roadway, and on æsthetic grounds the design chosen was one consisting of arches stiffened by plate web girders, with no obstruction other than vertical tie bars in the spaces between the arches and the roadway. The tie bars are of circular section and interfere very little with visibility. A separate superstructure is provided for each of the two carriage-ways of the Reichsautobahn, and the arches on either side of these are connected overhead by wind lattice bracing transmitting its load to the abutments through inclined portal frames. The bridge, which is shown in Fig. 7, is of entirely welded construction in high-tensile structural steel; the welding of the main girders was carried out in revolving supports on the falsework. As the roadways over the bridge are on a curve, the main girders of each superstructure have been erected at different levels and the cross girders built to a slope corresponding with that of the reinforced concrete running surface. Figure 8 shows the construction over the end bearings, where the web plate of the stiffening girder projects into the space between the walls of the arch and is connected to them by cross plates; the wall plates of the arch are further covered by plates which enclose the stiffening girder and are connected to its web by vertical strips. The last mentioned plates have openings to allow access for welding the inside seams. The appearance of the bridge is light and open, while at the same time powerful. It is the largest welded bridge in the world.

The Reichsautobahn bridge over the Lech, near Augsburg, is very similar to that last described and is likewise of welded construction, but the span, 93.5 m. (306.7 ft.), is a little less. The Lech bridge differs, however, from that at Duisburg in the absence of diagonal members in the wind bracing, which instead takes the form of portal frames having cross members at right angles to the center line of the bridge only—an arrange-

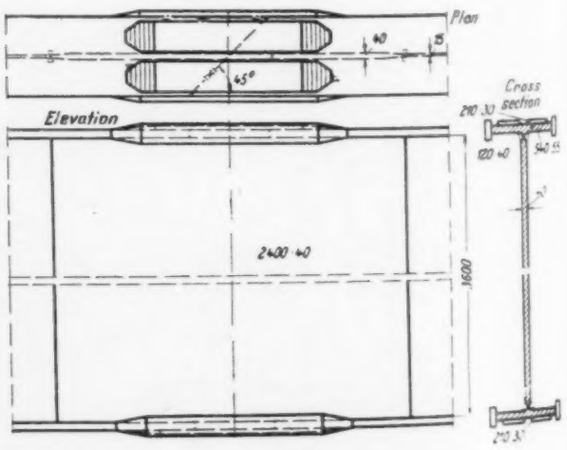


Fig. 12

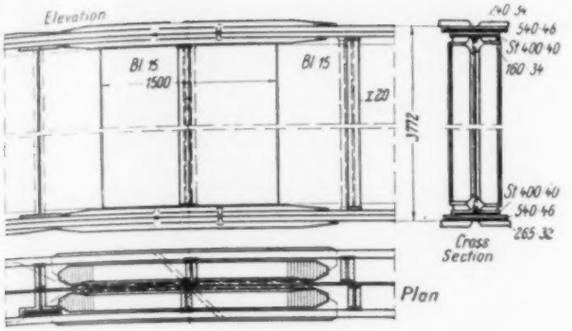


Fig. 13

ment which confers an even lighter and more open appearance. Figure 9 shows the construction over the supports, which again is simpler and more rigid than in the Duisburg bridge; the arch is of box section open underneath, and develops its thrust against a steel casting which fits into the stiffening girder and is welded to the web plate of the latter. The wind bracing members are of similar but smaller cross section (Fig. 10), connected by gussets at the top to the upper plate of the arch. The suspender bars, of circular section 65 mm. (2.56 in.) in diameter, are slotted at each end, the lower slot being circular to receive a bolt which passes through two plates connected to the web plate of the stiffening girder, the upper slot rectangular to accommodate two wedges of which the lower one bears on a plate carried between two vertical ribs across the arch.

The Rügendamm Bridge

The line of the Rügendamm dyke between the mainland and the island of Rügen includes two bridges, Ziegelgraben and Strelasund, carrying railway and road traffic by separate superstructures but on common supports. The railway bridges, but not the road bridges, are of welded construction, the reason for welding not having been used in the latter being that the fabricating firm concerned had not, at the time, sufficient experience in the welding of large bridges.

The Ziegelgraben bridge has three openings, the two outer ones measuring 52 m. (170.6 ft.) each, being spanned by fixed plate web girders, and the central span of 29 m. (95.1 ft.) by plate web girders forming a bascule, with counterweights (Fig. 11). The effect of the solid webbed construction adopted for the girders, towers and counterweight arms is to confer an impression of strength

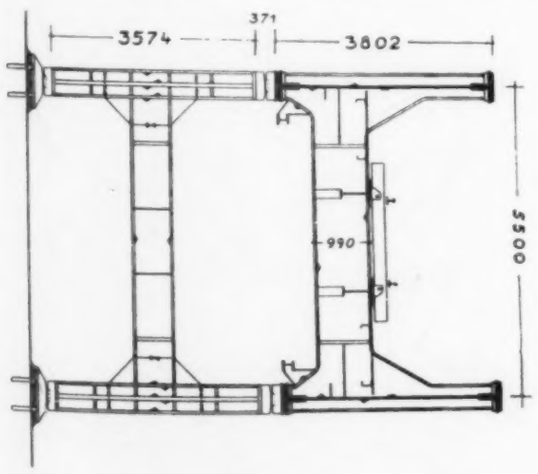


Fig. 14

and massiveness combined with simplicity while making the function of a bascule bridge clearly apparent to the lay observer.

The Strelasund bridge consists of ten openings, amounting in all to 540 m. (1771.6 ft.), situated in a portion of the strait of that name. The separate railway and highway bridges consist of plate webbed girders each of which is continuous over five spans of 54 m. (177.2 ft.). There are altogether nine piers, of which the third and seventh are built solid up to the underside of the girders, and carry fixed bearings, in order to resist braking stresses; the remaining piers extend only high enough to be above high-water level where they carry hinged bearing supporting portal frames on which, in turn, the railway and road bridges are borne. Movable bearings are fitted over the abutments also, so that the whole of the horizontal thrust due to braking effects is taken by the braking piers. Expansion joints exist over the central pier and over the abutments.

Further reference will be made here only to the welded railway bridge. One of the two halves of this bridge which meet at the expansion joint over the central pier was constructed by the firm of Dörnen, in Dortmund, the other half by Friedrich Krupp, of Rheinhausen, and each firm chose a radically different method of erection for their part of the superstructure.

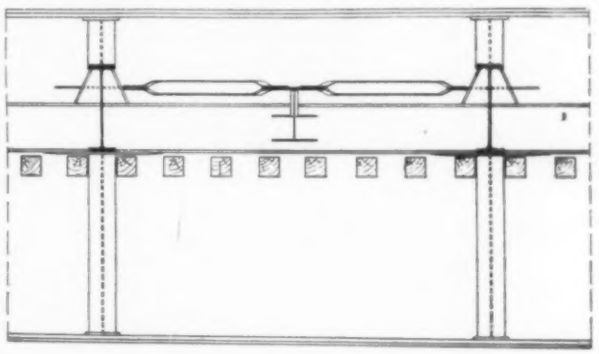


Fig. 15

The following was the procedure adopted by the firm of Dörnen who were responsible for that half of the bridge which abuts on the island of Rügen. The shore ends of the main girders were completely fabricated in the shops in single pieces 61 m. (200.1 ft.) long; these were transported by rail to Stralsund Harbour where they were picked up by a floating crane, carried into position, and lowered with one end on the abutment and the other projecting 7 m. (23.0 ft.) beyond the portal frame standing on the first pier. The remaining lengths of each girder were then brought into place by the same means—firstly, three successive lengths of 54 m. (177.1 ft.), then the closing length (to the middle of the bridge as a whole) of 47 m. (154.2 ft.)—connecting the landward end of each successive length of girder to the projecting end of the girder before, and cantilevering the free end over the next pier support ($61 + 3 \times 54 + 47 = 270$ m., the half length of the bridge). Special equipment was provided for suspending the abutting ends opposite one another in the cantilevered position. One of the site joints as used by Dörnen is illustrated in Fig. 12; the web plate, normally 15 mm. (0.59 in.) thick, is made 40 mm. (1.57 in.) thick over a length of 2.4 m. (7.9 ft.) at the joint, in order to reduce the stresses is the "bulged plates" (Dörnen system) used for the flanges; there are, therefore, two joints in the web, at this spacing; these joints are butt-welded double-V seams. The flange joints, top

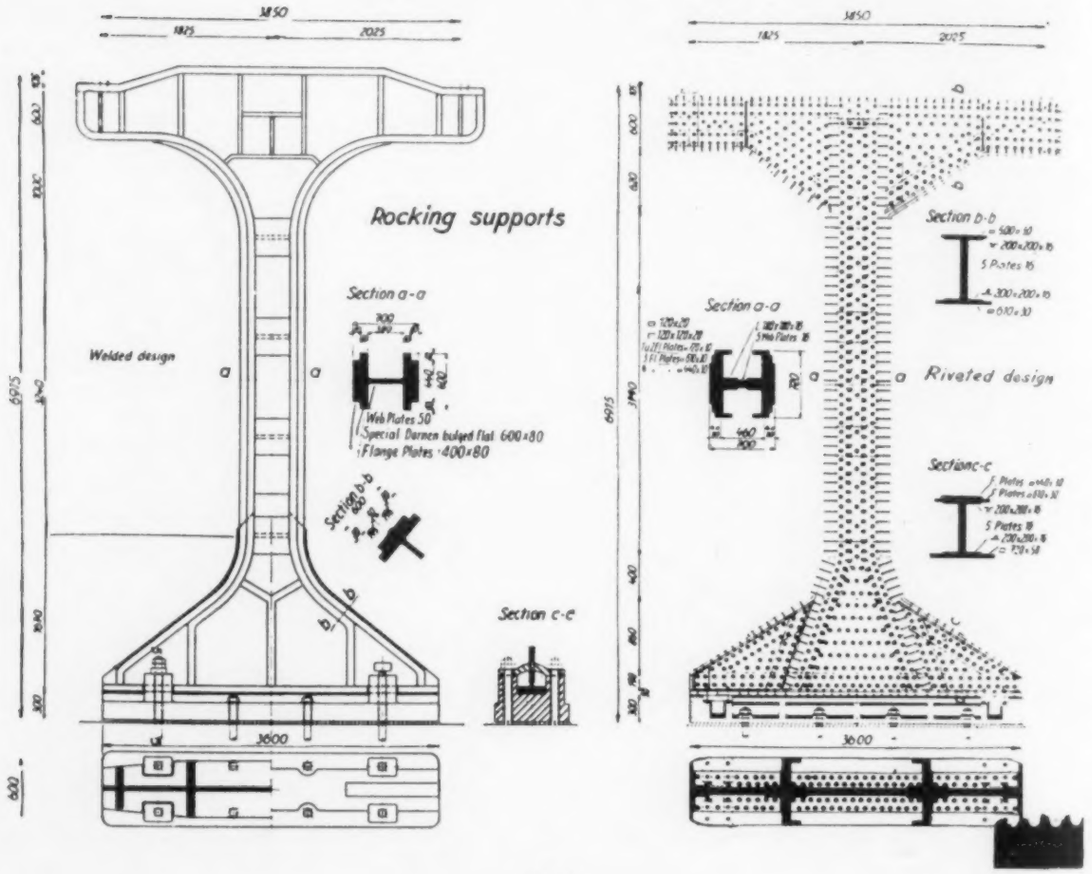


Fig. 16

and bottom, are of the same type, but at an angle of 45°, and are midway between the two web joints; they are further reinforced by small cover straps 120 × 40 mm. (4.72 × 1.57 in.) in cross section affixed to the edges of the "bulged" flange plates, and by cover straps 210 × 30 mm. (8.26 × 1.18 in.) placed flat against the upper surface of the top flange and the under surface of the bottom flanges, these reinforcing plates having been adopted on account of the heavy dynamic stresses that arise under railway traffic.

The following was the procedure used in welding. Firstly, the upper Vs of the double-V seams, in the top and bottom flanges simultaneously, were filled with weld-metal half-way up the V; then the lower Vs across the two flanges simultaneously were likewise half filled, by welding in the overhead position. During these operations the flanges were kept in contact by turnbuckles drawing them together with a force of about 10 tons. Next, the remaining joint in the web was welded with a double-V seam (the joint at the other end of the thickened piece of web plate having already been made in the shops). Then the butt joints in the flanges were completed, the tension in the turnbuckles being increased to 20 tons. Next the fillet welds between the web and the flanges were completed across the joint. Finally, the edge cover straps and the straps on the outer surfaces of both flanges were welded, working from the center outward. The attachment of these vertical and horizontal cover straps served to press the two sides of the butt joint together, thereby lessening the effect of any shrinkage stresses developed in welding the latter.

The procedure adopted by the other firm, Friedrich Krupp, also involved the delivery of the main girders on the site in long pieces, but the sections were welded together in a rotating support erected on the dyke behind the abutment of the bridge, and the decking was there assembled complete: when this had been done the whole bridge was moved bodily, at first a few meters transversely and then more than 270 m. (886 ft.) lengthwise over the five openings, and finally lowered several meters into its final position.

The type of site joint used in the portion of the bridge erected by Krupp is shown in Fig. 13. Here again a section of web plate 1.5 m. (4.9 ft.) in length is specially introduced at the joint, but like the remainder of the web it is only 15 mm. (0.59 in.) thick, its object being to enable the butt joints in the web to be welded free from shrinkage stresses. These are plain butt joints of V-section. Midway between them are the butt joints in the flanges, inclined at an angle of 45°, the latter being each composed of one plate of 540 × 46 mm. (21.26 × 1.81 in.) and one special Krupp rolling of 400 × 40 mm. (15.70 × 1.57 in.). The butt joint is a U-seam in each of these sections, and horizontal cover straps are provided, above and below the butt joint, for the reasons already explained.

The procedure in welding was as follows. The girder was placed in a vertical position and, with the joint portion of the web plate temporarily omitted, the lower half of the U-seam above the top flange, and likewise above the bottom flange, was welded. The girder was turned through 180° and the roots of these seams run over from the back, and the second of the U-seams now uppermost, was welded in its turn. The girder was again turned through 180° and the remaining halves of the first made welds completed. In order to minimize shrinkage stresses in the U-seams the girder was supported on small rollers allowing longitudinal movement.

Then the girder was brought to a horizontal position and the section of web plate 1.5 m. (4.9 ft.) long was placed in position and welded by V-seams to the adjoining web and to the special Krupp flange plate; the short piece of web plate had been slightly dished, and the effect of the shrinkage developed in the V-seams connecting it to the web plate on each side was to flatten it, thus mitigating any shrinkage stresses that might otherwise have been developed. After these seams had been welded, V-seams were made between the short piece of web plate and the two flanges. The girder was again turned through 180° and the roots of the V-seams run over from the back. For constructional reasons the horizontal cover straps on the flanges could not be affixed until after the decking of the bridge had been welded in position, so that the straps underneath had to be welded in the overhead position.

Figure 14 shows the cross section of the bridge with one of the welded portal frames on rocker bearings which serve as supports. The cross girders are designed in the form of rigid frames extending both to the upper and the lower flanges of the main girders, and the latter are 5.5 m. (18.0 ft.) apart, center to center, and 3.8 m. (12.5 ft.) in depth. The construction of the portal frames is clearly apparent; the cross member is at the middle height of the stanchions, to which it is connected by gussets.

The longitudinal section, Fig. 15, will serve to indicate how the longitudinal rail bearers are connected to the cross girders by means of cantilever members welded underneath the ends of the former and reaching to the lower flanges of the latter. The end of each rail bearer is connected to the next by a cover strap over the top of the intervening cross girder.

Naturally some difficulties arose in the course of welding the site joints on a bridge of this magnitude, but all of them were successfully overcome. X-ray examination of the seams played an exceptionally important part in ensuring this, and provides a method with which no responsible engineer concerned with heavy butt welds can afford to dispense.

Another example of a large welded structure is provided by the bridge which serves to carry frequent passenger traffic over the goods station at Altoona. The passenger line is on a curve of 350 m. (1148 ft.) radius and most of the supports for the bridge are single column frames on rocker bearings; some doubt was at first entertained whether these should be of riveted or of welded construction, but closer investigation showed that the former would be very difficult to carry out and that the welded design, appearing on the left of Fig. 16, would be far easier.

World's Largest Rotary Lime Kiln

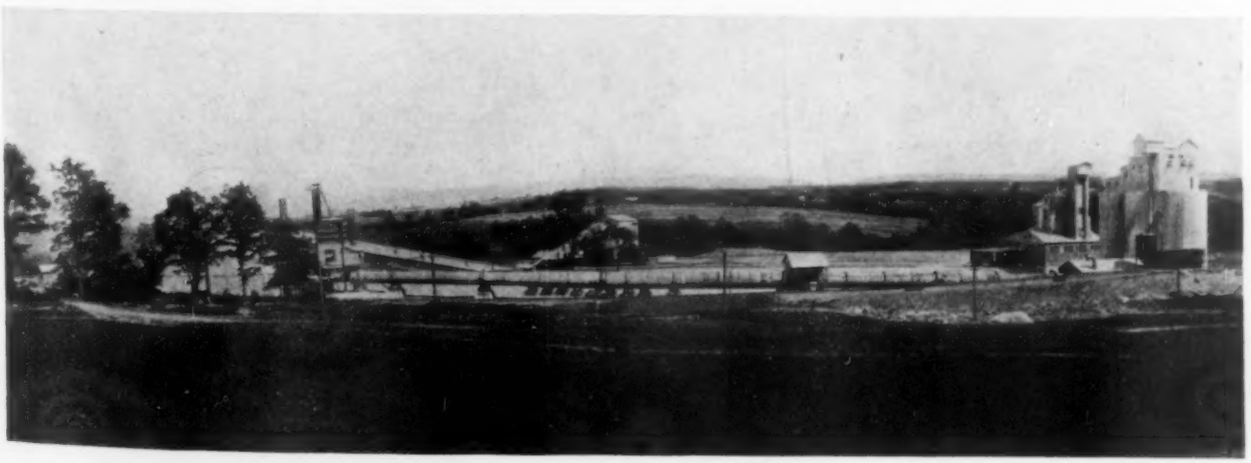
By A. F. DAVIS†

SHOWN in the accompanying illustration is what is believed to be the world's largest rotary lime kiln recently completed at the Chemical Lime Company in Bellefonte, Pa. The kiln was manufactured by the Traylor Engineering and Manufacturing Company, Allentown, Pa., and is entirely electric welded.

†Secretary, The James F. Lincoln Arc Welding Foundation.

The kiln is 400 feet in length, consisting of a 300-foot zone, a 10-foot tapered zone, and a 90-foot preheating zone. Diameter of the pipe through the 300-foot zone is 8 feet 6 inches and 7 feet through the preheating zone. The kiln has a capacity of 200 tons of lime per day. The revolving load of the kiln is 1000 tons when empty. This includes 568 tons of fire brick. Temperature of operation varies between 400 degrees at one end and 2100 degrees at the other. The rate of rotation is one revolution per minute. The kiln is driven by a 60 horsepower electric motor, driving through a gear reduction. The unit is also adapted for drive by a 110 horsepower gasoline which may be engaged by a clutch arrangement in case of electrical power failure.

This huge kiln is fabricated of $^{7}/_{8}$-inch steel plate throughout except under the tires where the thickness is one inch. There are a total of 21 arc-welded sections in the kiln.



Some Factors to Be Considered in the Choice of a Welding Process*

By LOUIS J. LARSON†

MANY factors enter into the choice of the welding process to be used for any given job but the dominating one is the cost of obtaining the required results. This does not mean that the cheapest welding process will always be used. The process chosen must first of all be capable of making the required weld and the weld obtained must serve the purpose for which it is intended. When welding is used for making a repair the choice of process is further limited by the welding equipment available. If the work cannot be moved, the ease or convenience of moving the welding equipment to the work may determine which process is used. Even for making repairs the over-all cost, including the cost of materials and any equipment which must be purchased, the expense of moving the equipment to the work or of moving the work to the equipment, and the loss due to shut-down of the structure or machine being repaired, is an important factor in choosing the process to be used. In the manufacture of new products cost must obviously be given careful consideration. Cost in this case includes not only the expense of the actual welding operation, such as labor, material and power but also maintenance and depreciation of equipment.

Welding processes differ greatly in their inherent characteristics and each has some advantages and some disadvantages. A summary of the various processes will indicate some of the possibilities and limitations of each. Welding may be divided into two general classes: (1) those processes in which the material is heated to the plastic state and the actual weld is accomplished by means of pressure; (2) the processes in which the metal is heated to the molten state and no pressure is applied. In the first group the heating may be accomplished by any suitable means such as fire, electrical resistance or electrical induction. The pressure may be applied intermittently by hammer blows or continuously by a press.

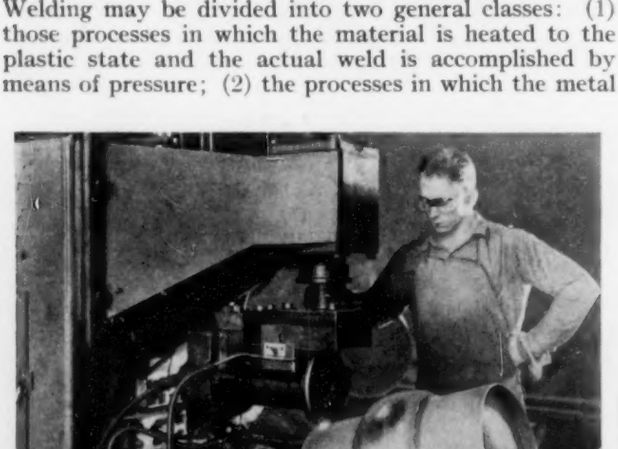


Fig. 1—Seam Welding Head to Shell of Beer Barrel

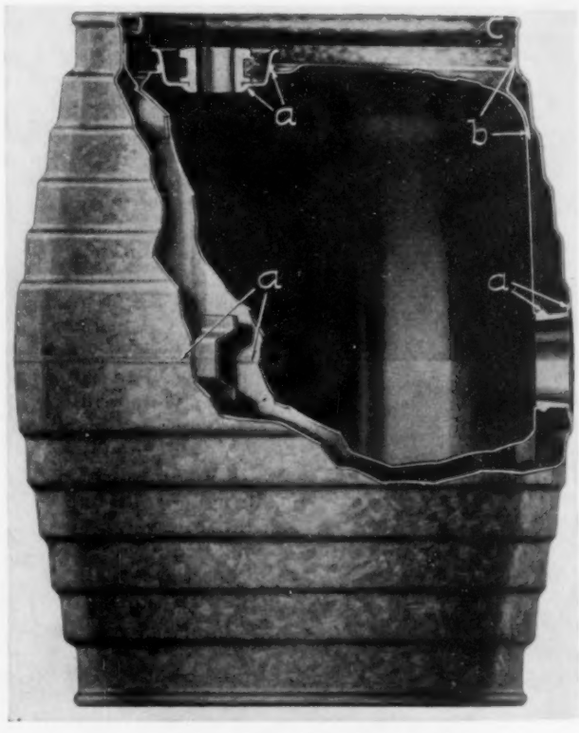


Fig. 2—Double Shell Type of Beer Barrel

Pressure Welding Processes

Fire and Pressure

The first combination, namely, fire and hammer blows is exemplified by the old fashioned blacksmith weld. In this process the pieces to be welded are beveled or scarfed, heated in a forge fire to the proper temperature for welding, then placed together and hammered to produce the weld. This method was developed to its highest degree in the manufacture of large hammer welded vessels. In the fabrication of such vessels plates were formed into cylinders and the longitudinal seams heated to welding temperature and hammered with large forging hammers. Circular seams joining the ring sections or a ring section and a head were welded together in the same manner. Vessels several feet in diameter were made in this manner, of materials up to 1-1/2 in. or even more in thickness. In the manufacture of lap welded pipe the process was

* From a paper presented before Kansas City Section of American Welding Society, May 17, 1937.

† A. O. Smith Corporation.

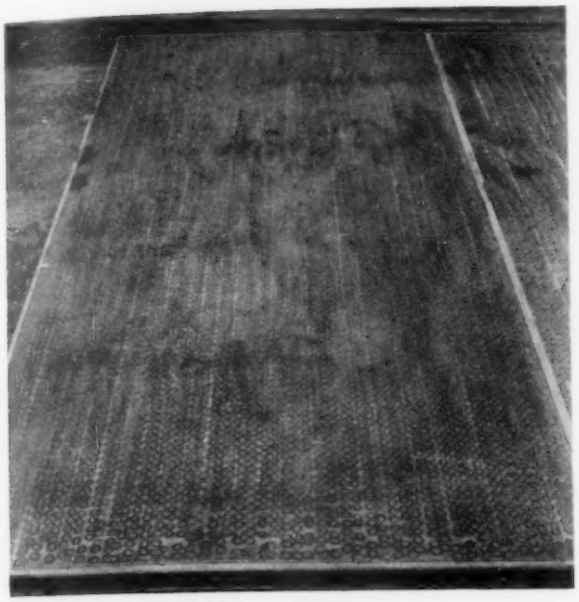


Fig. 3—Spot Welded Lined Plate for Pressure Vessel

basically the same but the hammering was replaced by pressure produced by rolls passing along the length of the seam. This process in all its modifications is limited to materials which are easily weldable such as mild steel and wrought iron, and even on these materials the strength of the weld depends to a great extent on the skill of the operator. It is difficult, particularly on the thicker sections, to prevent the inclusion of slag or scale which results in unfused areas in the joint. Visual inspection of the finished weld does not furnish conclusive evidence as to whether or not the weld is sound. The outer surfaces may be fused so as to give the appearance of a perfect weld even though the center is unfused. As a manufacturing process this method has been largely replaced by others which were developed later.

Electric Heat and Pressure

In this group of processes, which includes resistance butt welding, spot welding and seam welding, the heat is produced by resistance in an electrical circuit. The source of power is generally an A.C. transformer since high current values at low voltages are required.

The resistance butt weld is used to join two pieces of substantially the same cross section in the plane of the weld such as pipe and other shapes which can be formed to meet alone one line or formed in halves so as to butt along two lines. The parts to be welded are formed and the welding edges are trimmed or machined so that when the two parts are assembled there is good contact along the entire seam to be welded. The parts are placed in dies or fixtures which hold them in position and also force the two pieces together with considerable pressure. An electric current of suitable amperage is passed across the joint between the two pieces which develops a large amount of heat at the contact surfaces between the parts to be welded, due to the high resistance at this point. The current is allowed to flow for a sufficient length of time to bring this contact surface up to the welding temperature and the high pressure produces the weld. One of the draw backs of the resistance butt weld is the difficulty of obtaining uniform heating along the seam. If the contact is not uniform more current passes through the areas having good contact resulting in overheating these areas compared to those which have little or no contact. As a result of the unequal heating, welds of this type are likely to be non-uniform, and defective welds are not revealed by visual inspection of the finished article. The process requires heavy, rigid, mechanical equipment and electrical equipment of high current capacity. The expense of such equipment is prohibitive except for quantity production involving many pieces of one kind. As a method of manufacture the process has been quite generally superseded by others which produce more uniform results.

A variation of the regular resistance butt-welding process is known as percussion welding. In this process, the current is furnished by a discharge from a condenser and the pressure is applied by striking together the two pieces to be welded. The timing is automatic since it is governed by the length of time required to discharge the condenser and the amount of current is governed by the capacity of the condenser. This process is said to be particularly useful for welding dissimilar materials, but is limited to relatively small welds. The resistance spot weld is a convenient method of making lap joints between plates or pieces having flat areas. These welds act in the same manner as rivets but they eliminate the necessity of piercing rivet holes. Furthermore, since there are no holes, there is no decrease in the tensile strength of the members along the line of welds. The pieces to be welded are located in the proper position relative to one another and placed between two opposing electrodes of a spot welding machine. By mechanical means one electrode is moved toward the other and this operation clamps or presses the two pieces of material into contact at the area to be welded. The current passes from one electrode through the two pieces of material into the other electrode. With a current of sufficient amperage a welding heat is quickly produced at the contact between the two pieces of material. The size and shape of the electrodes and the material from which the electrodes are made are very important factors in the success of the spot welding operation. The electrode material must have a high electrical and thermal conductivity to prevent the electrodes from sticking or welding into the work and must be hard enough to prevent upsetting or mushrooming under the pressures required to force the two pieces of the work together. For successful spot welding at least one of the pieces must be thin enough so that the pressure of the electrodes is sufficient to produce proper contact at the area to be welded.

To increase production and thus reduce cost, attempts

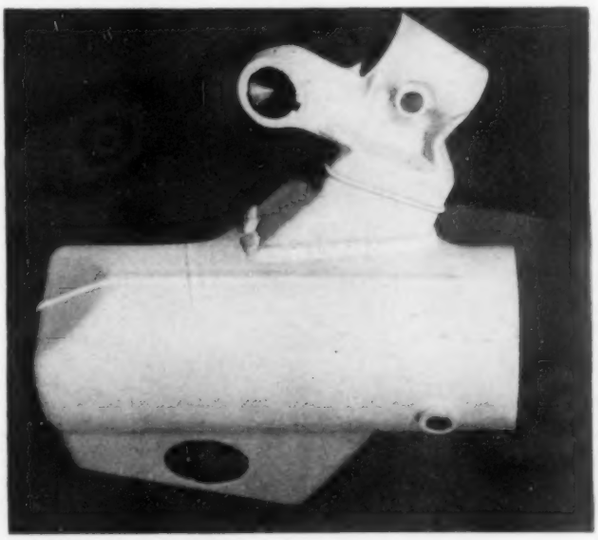


Fig. 4—Knee-Action Housing for Automobile

have been made to make more than one spot at a time. When several electrodes are connected to one transformer resulting in two or more electrical circuits in parallel, it is very difficult to obtain equal distribution of current through the several spots because of the variation in conditions at the contact areas. Projection welding overcomes this difficulty to some extent. For this process projections are formed on the surface of one of the pieces to be welded, preferably the heavier of the two at the points to be welded. When the other piece is placed in position and the current passed from one electrode to the other, it must pass through these projections because they are the only points of contact. For making projection welds it is generally possible to use electrodes in the form of flat blocks which are much cheaper to maintain than the usual electrode type.

Although in most applications of spot welding the electrodes are located on opposite sides of the work, there are some applications for which this arrangement is difficult and impractical. This is particularly true when the pieces to be welded are large and the spots are far from the edge. In such cases both electrodes may be placed on the same side of the work. When a thin sheet is to be welded onto a heavy piece both electrodes are located on the thin piece and the current flows from one electrode through the thin sheet into the heavy piece and back through the thin sheet to the other electrode, the path of the current being similar to a U.

When it is desired to make a leak proof joint between the two pieces of thin material a seam weld is often used. This is nothing more than a series of overlapping spots. For making such a weld, the electrodes are generally wheels or disks which roll along the seam to be welded. The current is switched on and off at regular intervals of the desired length. Accurate timing of the current is very essential because the welding time must be very short, usually only a few cycles of 60 cycle current. Mechanical timers are not the most suitable for this work, but electrical timers are available which accurately control the time to any given number of cycles, sometimes as low as one cycle.

As a source of heat it has been proposed to use the inductive effect of high frequency A.C. current. This method has been demonstrated as being successful in heating materials to a high temperature and is used for local surface hardening, but, so far, there have been no practical applications of welding by this process. This method of heating requires special and expensive generating equipment, and for that reason, may not prove to be economical. Under proper conditions it should have some advantages over the ordinary resistance butt weld since the heating will be more nearly uniform along the length of the seam and will also be independent of the degree of contact at various points. After the material is heated to welding temperature the procedure is similar to that used in resistance butt welding.

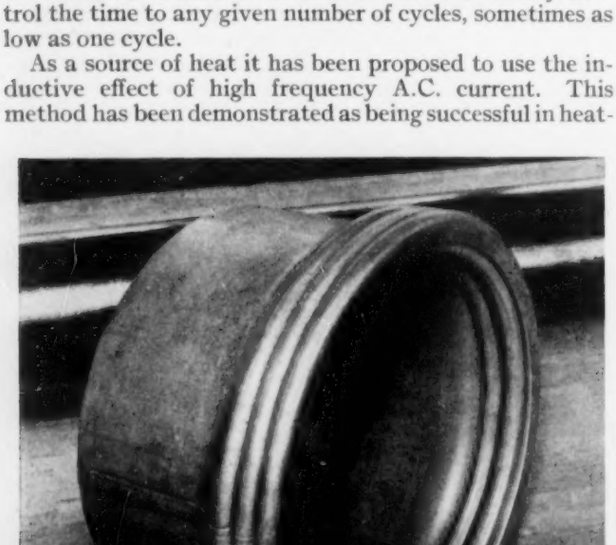


Fig. 5—Pipe After Crush Test. Result of Crush Test on Smithweld Gas Line Pipe. One Piece was Sawed Out to Show Folds and the Freedom from Cracks

Fig. 6—Making Bell Hole Weld on Pipe in Field

Flash Welding

In the method known as flash welding the set-up is similar to that used for resistance butt welding. The parts to be welded are brought into contact but no pressure is applied. As soon as the contact is formed a very high current passes through the original contact areas and literally explodes the metal out from between the two pieces at these points. In observing the flash welding operation it appears that the action is continuous all along the seam, but high speed motion pictures show that a series of arcs of very short duration are formed at various points along the seam.[1] These arcs are of such short duration and the point of arcing changes so rapidly that it gives the appearance of a continuous arc. This arcing or flashing as it is called heats the metal adjacent to the joint. After a sufficient amount of metal has been melted or burned away to heat the edges up to a welding heat, the pieces are forced together under high pressure and the current is cut off. This high pressure squeezes out the oxides and slag as well as any molten metal. At the seam the material which is squeezed out forms a ridge or flash on each side of the joint. The quality of the welds produced by this process is excellent and is not dependent upon a perfect contact between the two pieces being welded since the flashing operation quickly removes the high spots. This self-corrective feature is one of the important differences between this process and resistance butt welding.

Flash welding may be applied to a large variety of products. Longitudinal and circular seams in tubular products and irregular seams such as joints in automobile bodies are typical examples. Material ranging in thickness from a few hundredths of an inch to several inches can be welded with proper equipment. The upper limit

[1] W. E. Crawford and Walther Richter, "High-Speed Motion Pictures of Flash Welding," THE WELDING JOURNAL, 15, 12 (1936).

Fig. 7—Arc-Welded Machine Tool Base

is a question of cross-sectional area rather than thickness of stock and is determined by the capacity of the welding machine. Plate material having a cross section of as much as 200 sq. in. has been welded. The time required to make a flash weld is independent of the length of seam and is a matter of seconds. Although this process has been used most extensively for welding mild steel it can be used for other ferrous alloys and probably for some nonferrous materials.

Flash welding has many advantages but for some applications it may not be economical even when the parts are such that the process can be used. It requires heavy and expensive equipment from both the mechanical and electrical standpoint. The dies and contacts required to hold the pieces in alignment and to conduct the current into the work are costly and require considerable maintenance; and these dies can be used only for pieces of the same shape. Consequently the process cannot be justified except for manufacturing a large number of similar pieces. After welding it is generally necessary to remove the flash and this operation may take several times as long as the welding operation, and actually cost more than welding. All of these factors must be considered since they are part of the total cost of welding.

Fusion Welding Processes

In the fusion welding processes the metal which joins the two parts is heated above the melting temperature. The required heat may be produced by a chemical reaction as in Thermit process, by combustion of gases as in gas welding or by an electric arc in the arc welding processes.

Thermit Process

When a properly proportioned mixture of aluminum powder and iron oxide is ignited a chemical reaction takes place and the aluminum reacts with the oxygen from the iron oxide to produce pure iron and a slag of aluminum oxide. This reaction takes place rapidly with the liberation of sufficient heat to melt the iron and the slag. This molten iron is poured into a mold which has previously been built around the parts to be welded. Although the weld metal is cast, it is very pure and of high quality compared to the usual casting, and it is possible to further improve its properties by adding any desired alloys. The process is costly because of the necessity of making the mold and because the materials required for the Thermit reaction are expensive. Thermit welding has had its greatest application in repairing frames of heavy machinery and locomotives. Recently the method has been used in welding the joints of railroad rails on experimental sections of track.[2] In this application the process used is a combination of Thermit and resistance butt welding. The ends of the rail heads are machined square and the portion of the rail below the head is cut out, leaving a groove about $1/2$ in. wide for the Thermit weld. Enough molten iron is poured into the mold to fill it up to the lower side of the head of the rail. This molten metal as well as the molten slag heats the heads of the rails up to the welding temperature and the actual weld in the head is then accomplished by forcing the rails ends together with a screw clamp which is attached to the rails on either side of the joint. This results in a continuous rail head of a uniform composition which wears evenly. From several sections of test track, some of them up to two miles long, it has been found that welded rails do not give the anticipated trouble due to expansion in hot weather. Having the rails welded instead of connected by the usual type of rail joint reduces maintenance, increases riding comfort and eliminates considerable traffic noise. From the indications so far it appears that this method may be quite extensively used on rails in the future.

Gas Welding

In the various gas welding processes metal is heated by the combustion of some kind of gas with oxygen. Acetylene is most frequently used, although for certain purposes hydrogen is quite satisfactory, and, for welding some materials such as aluminum, the oxyhydrogen process is more satisfactory than oxyacetylene. The oxyacetylene flame is the hottest flame obtainable by combustion of the common gases, its temperature being around 3500° F. Gas welding is suitable for butt joints, fillet welds or corner welds and it may be used for welding in any posi-

Fig. 8—Arc-Welded Pressure Vessel

[2] J. H. Deppeler, "Thermit Welding," The Welding Journal, 15, 2 (1936).

tion, that, is horizontal, vertical or overhead. In making butt joints in thin materials it is sometimes sufficient to melt the sheets adjacent to the joint and allow them to fuse together without adding any metal. Butt joints in thin material are also sometimes made by turning up the edge of one or both of the plates adjacent to the seam and melting this material into the joint for filler metal. On heavier material a filler rod of about the same composition as the base material is added, in order to build up the weld to the required thickness. Oxyactylene welding may be used on most ferrous alloys and many non-ferrous alloys. For welding mild steel no flux is necessary, but on such materials such as stainless steel and aluminum, special fluxes are required. The gas welding process has the advantage that the heat is under good control. The size of flame may be controlled, first by the size of welding tip used and second by the gas pressure. The operator can further control the heat by the rate of travel and by the position of the torch. For welding light gages this accurate control of the amount of heat is very essential. On heavy materials the process has the disadvantage that the heating is not rapid enough and, as a consequence, the metal being welded conducts too much heat away from the joint which results in slowing up the welding process and also in overheating and often warping of the structure. The process is very flexible, and it may be used in out of the way places, the only equipment necessary being the tanks of oxygen and acetylene with suitable gages, hoses and welding torches. These can easily be transported to any place that may be desired. The process has been used quite extensively in welding oil and gas pipe lines in the field, and it is also being used in welding steam piping and plumbing in new buildings. In the manufacture of new products its use is generally limited to relatively light gages of material.

Atomic Hydrogen

This is not strictly a gas welding process, but, in many respects, it is very similar to oxyacetylene welding. In the atomic hydrogen process the heat is obtained from an arc struck between two tungsten electrodes which make an angle of about 45° with each other. The welding head is so made that a sleeve of hydrogen gas surrounds each of the electrodes. When the arc is struck between the electrodes the hydrogen flowing through the arc is converted from molecular to atomic hydrogen. This transformation absorbs a large amount of heat. As the hydrogen moves away from the arc it again goes back to the molecular state giving up this same amount of heat. The fan-shaped flame which forms between the tungsten electrodes is used in the same manner as the ordinary gas welding flame. The atomic hydrogen process is quite expensive especially for heavier work because of the cost of the hydrogen and the tungsten electrodes used. For certain purposes, however, the process has a number of definite advantages. The hydrogen not only acts as a carrier for the heat energy but also furnishes complete protection against oxidation and, as a result, it is possible to deposit, without any serious change of composition, many alloys which are readily oxidized in the air. Its use for welding mild steel is rather limited because other processes are generally cheaper.

Arc Welding

Arc welding may be divided into two classes, carbon arc welding and metallic arc welding. In carbon arc welding an electrode consisting of a carbon or graphite rod is connected to the negative terminal of a D.C. generator, and the work is connected to the other terminal. The heat for melting the metal is produced by an arc formed between the carbon rod and the work. The temperature

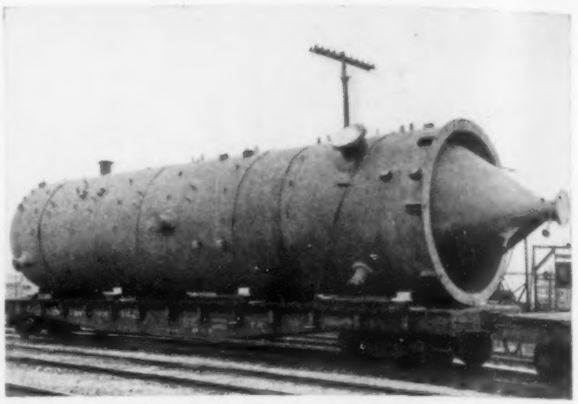


Fig. 9—Arc-Welded Pressure Vessel of 2½% Ni Steel

of the carbon is very high, being estimated as high as 11,000° F. With this process, using automatic equipment, it is possible to penetrate ⅜ of an inch of steel and by welding from both sides it is possible to completely penetrate a ¾-in. plate without a groove or scarf. A heavy layer of special flux is used to cover the weld bead when welds of the best quality are required. Filler metal must be added to build the bead up to a required dimension. The process is particularly convenient in welding material ¾ in. or less in thickness when advantage can be taken of the fact that no scarfing of the edges is necessary. It is also rapid and convenient in making corner welds and edge welds.

Metallic Arc Welding

In the metallic arc welding process a metal wire or rod is used as the electrode. When the rod is touched onto the work and then withdrawn slightly an arc is formed between the electrode and the work which fuses the rod and melts a crater or depression in the work. The metal from the electrode unites with the fused metal of the work thus forming a molton pool. The electrodes used in metallic arc welding may be bare, lightly coated or heavily covered. The properties of weld metal obtained with the use of bare electrodes differs so much from these welds made with covered electrodes that bare wire welding and covered electrode welding may be considered as two processes. Which process is chosen for a given application depends upon the quality of weld metal required. Tests for quality include metallurgical examinations, chemical analysis and physical tests.[3]

The results of the physical tests and metallographic examinations on bare wire weld metal and weld metal made with covered electrodes show that the bare wire welds in this material may have reasonably good strength but results become erratic on heavy material and the ductility and impact values are very low, whereas welds made with covered electrodes in any thickness of plate show physical properties substantially equal to or in excess of those of mild steel.

Bare wire welding may be used in thinner materials when the ductility and toughness of the weld metal are not important. Bare electrodes are cheaper than covered electrodes but the saving in electrode cost is often more than offset by the increased cost of labor when manual welding is done. Bare wire lends itself more readily than covered electrodes to the use of automatic welding heads. With covered electrodes high quality weld metal can be

[3] For a discussion of the qualities of bare wire weld metal and of welds made with covered electrodes see L. J. Larson, "An Exploration of a Modern Welding Arc," THE WELDING JOURNAL, **15**, 18 (1936). For a more comprehensive metallurgical study see S. L. Hoyt, "Studies on the Metallurgy of Arc Deposited Weld Metal," *Trans: A. S. M.*, **23**, 61 (1935).

obtained in any thickness of plates commercially available. This method is also suitable for welding most alloy steels which are not too air hardening and for welding many non-ferrous materials.

Examples of Various Welding Processes

The following examples indicate the application of various welding processes in the manufacture of new products.

Figure 1 shows a seam welding machine making a joint between the head and shell of a barrel.

In fabricating the barrel shown in Fig. 2, four welding processes were used. The arc welds joining the bung and the tap to the shells and also joining the two halves of the inner and the outer shell are clearly visible at *a*. Seam welds, *b*, attach the supporting ring to the inner and outer shells. Leak proof joints were required at these points. The longitudinal seams of each half of the outer shell were flash welded and the ring between the shells at the girth joint was spot welded to one-half of the outer shell. Neither the flash welds nor the spot welds are visible in the photograph.

Figure 3 shows an unique application of spot welding. A stainless steel liner about $^1/_8$ in. thick was welded on one-inch centers to a heavy carbon steel plate. This lined carbon steel plate was then rolled into a cylinder to form a section of a pressure vessel.

Figure 4 shows two flash-welded joints and one arc-welded joint in a knee-action housing for an automobile. The piece of pipe shown in Fig. 5 was made from a sheet of steel formed into a cylinder and metallic arc welded along a longitudinal joint. After the severe deformation produced by a crush-test, the arc weld shows no cracks or evidence of failure.

In making a tie-in or bell-hole weld on a pipe line that cannot be rotated, it is necessary to weld in all positions from horizontal to overhead as is shown in Fig. 6. The portable field welding set for metallic arc welding this joint is visible in the background.

Frames and bases for machines such as shown in Fig. 7 may often be made from rolled plates welded with the metallic arc.

The application of metallic arc welding in the manufacturing of pressure vessels is shown in Fig. 8. The longitudinal and circular seams are butt welds. Fillet welds around the reinforcing collars and plug welds through these collars attach them to the shell sections.

Figure 9 shows an arc-welded vessel of about $2\,^1/_2\%$ nickel steel. With covered electrodes this material and many of the other alloy steels can be successfully welded.

These examples indicate a few applications of some of the welding processes. As has been shown, several processes may be used in the manufacturing of a single product. In the last analysis the welding process chosen should be the one which is most economical when proper consideration is given to cost of all factors such as labor, material, power and the welding equipment, including maintenance, chargeable to the job.

Gargantuan "Tomato" Huge All-Welded Gasoline Storage Tank

By R. B. REID*

AS PART of an extensive modernization program, the Sinclair Refining Company, East Chicago, Indiana, has completed the construction of the first of several new type gasoline storage tanks. Built in the shape of a huge steel "tomato," this tank is completely fabricated by arc welding. An idea of the amount of welding involved can be gained from the fact that the tank is 92 feet in diameter and 47 feet, six inches high, with a capacity of 40,000 barrels of casing-head gasoline.

One of the most important considerations in determining the shape of the new tank, as well as the method of fabrication, was the fact that the structure, when completed, would be subjected to a working pressure of 15 pounds per square inch. Unless high pressure is maintained within the storage tank, the gasoline will boil out. This type of tank was chosen because it permits the use of much greater internal pressures than the conventional type tank will withstand. Upon completion, the new tank was tested with a pressure of 17 pounds per square inch and only one leak was discovered. This was easily repaired and the company states that it is completely satisfied with the arc-welding method for the construction of tanks of this type.

Gasoline Storage Tank Being Arc Welded. Part of Modernization Program Being Conducted by the Sinclair Refining Co.

* News Bureau, General Electric Co.

Building Up Worm Hoist; Courtesy Air Reduction Sales Co.

Building with Welding

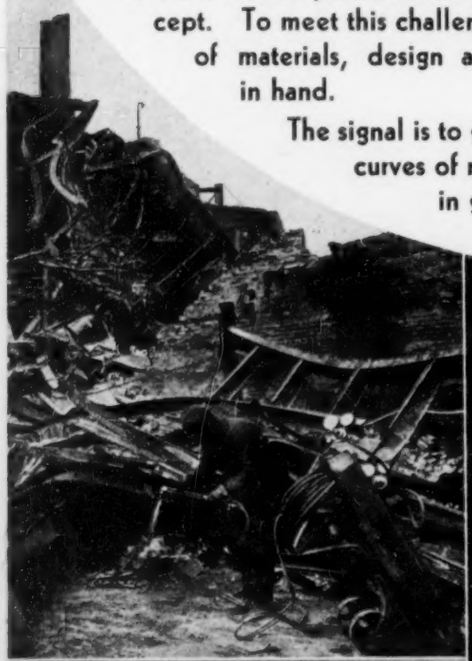
Welded structures, tanks, bridges and buildings are no longer a novelty. A milestone of progress was passed in the adoption by New York City of a new Building Code which permits the use of welding. Years of research and development, sound engineering designs and years of experience were forerunners of the acceptance of welding by the largest city in the world.

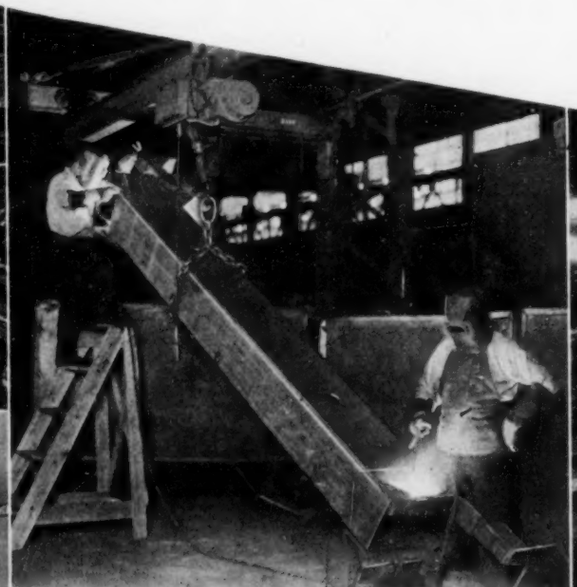
Welding makes possible a lighter, stiffer and more compact joint. The same degree of strength may at times be obtained with savings in cost. Typical examples of the latter are wind and earthquake bracing, girders and trusses. In crowded cities elimination of noise is a determining feature and it is reasonable to expect that the public, aided by noise abatement groups and health bodies, will in time demand ordinances making the use of welding mandatory.

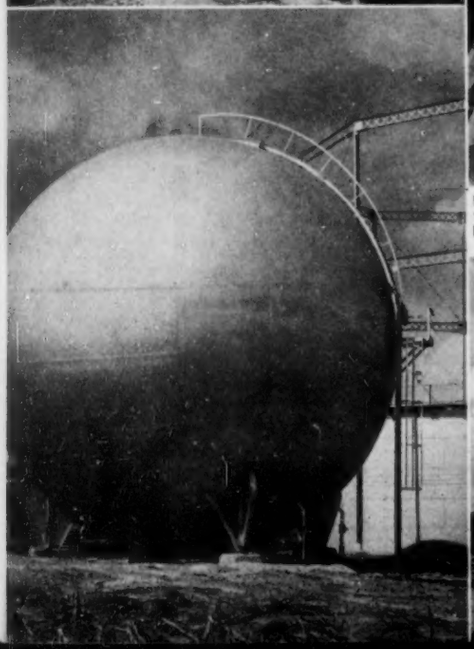
In its program of advancing the use of steel, the steel industry is willing to take its own medicine. Welded steel equipment and welding in maintenance are now the accepted methods.

In this new acceptance of welding there is a challenge which the industry and the Society accept. To meet this challenge of responsibility there will be stringent code requirements of materials, design and workmanship. Education, training and research go hand in hand.

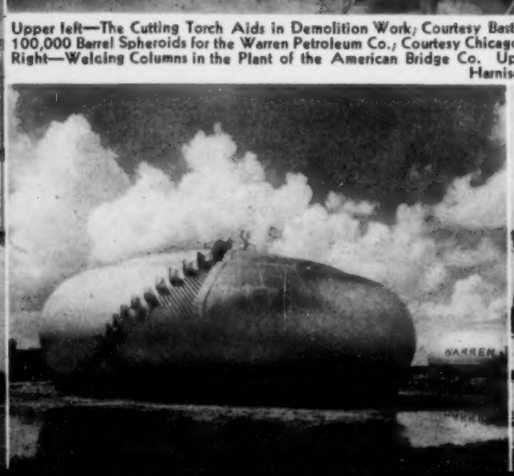
The signal is to go ahead but the industry will see to it that the speed around the curves of new developments will not be too great and that the brakes are in good working order.

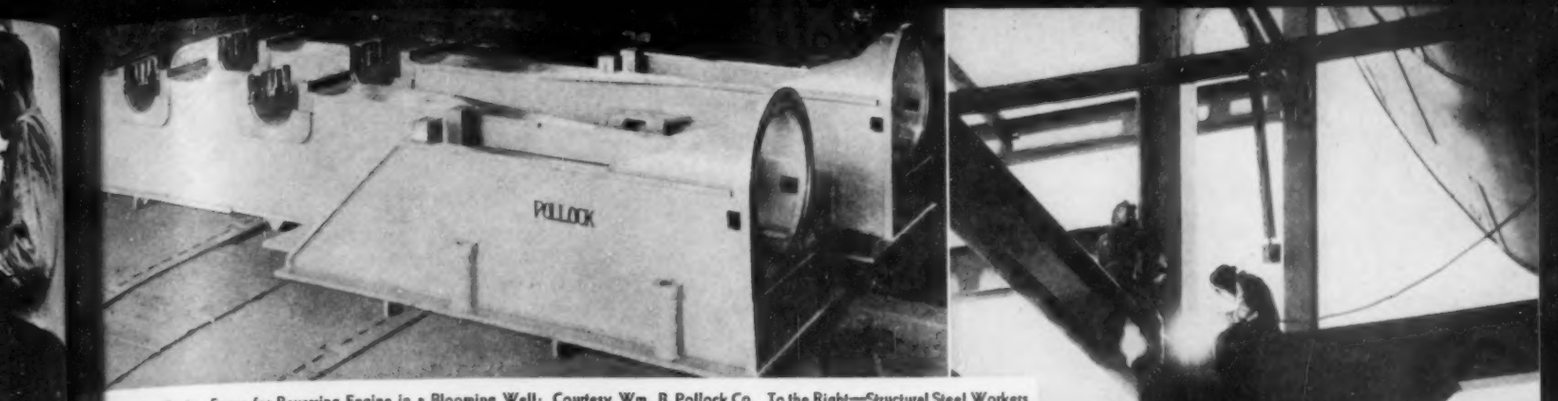




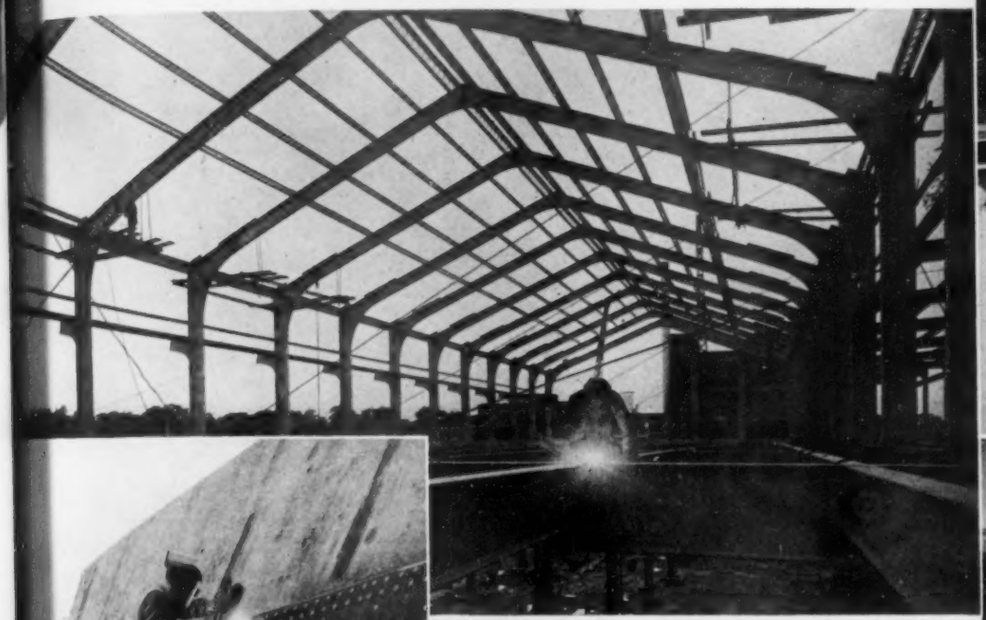


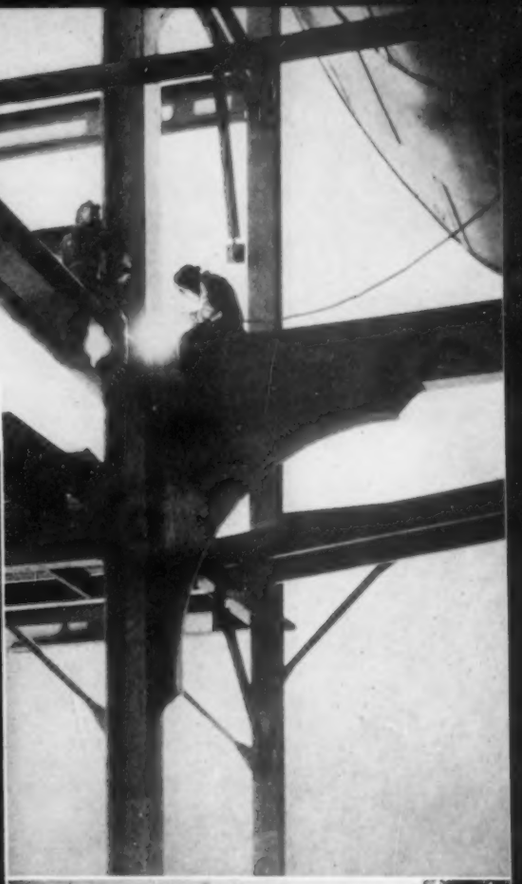
Upper left—The Cutting Torch Aids in Demolition Work; Courtesy Bastian Blessing Co. Left—200,000 Cu. Ft. Welded Hortonsphere and Below 100,000 Barrel Spheroids for the Warren Petroleum Co.; Courtesy Chicago Bridge and Iron Co. Lower Right—Tank of the Sinclair Refining Co. Upper Right—Welding Columns in the Plant of the American Bridge Co. Upper Center—Welding Heavy Box Section for Overhead Crane; Courtesy Harnischfeger Corp.



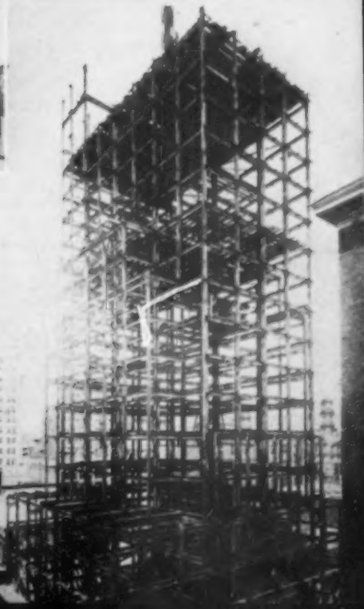


ove—An Engine Frame for Reversing Engine in a Blooming Mill; Courtesy Wm. B. Pollock Co. To the Right—Structural Steel Workers lding All Steel Addition to Power Plant; Courtesy Hobart Brothers Co. Below—All Welded 200,000 Sq. Ft. Addition to Lincoln Electric Company's Plant.

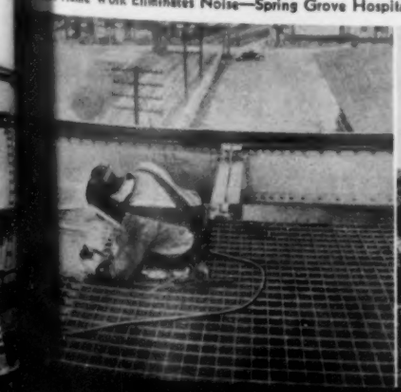


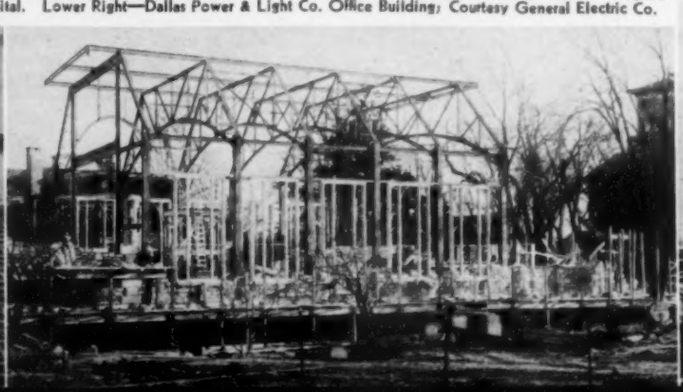


Left—Welding Skin Plates on Gates for a Movable Dam; Courtesy U. S. Steel Corp. Below—Schenectady State Armory and to the Right—14 Story Field Welded Boston Edison Electric Illuminating Co.; Courtesy General Electric Co.



—Coke Pusher for Carnegie-Illinois Steel Co.; Courtesy Wellman Engineering Co. Grandstand Built by Welding Section in Pipe; Courtesy The n Electric Co. Lower Left—Welding Floor Foundation Monongahela River Bridge; Courtesy U. S. Steel Corporation. Lower Center—Welded l Frame Work Eliminates Noise—Spring Grove Hospital. Lower Right—Dallas Power & Light Co. Office Building; Courtesy General Electric Co.





CURRENT WELDING LITERATURE

Aluminum. Oxyacetylene Welding of. F. Zimmermann. Aluminum & Non-Ferrous Rev. (Mar. 1937), vol. 2, no. 5, pp. 203–204; (Apr.), no. 6, pp. 231–232, and (May), no. 7, pp. 259–260.

Annealing of Welded Work, C. H. Jennings. Am. Soc. Naval Engrs. Jl. (May 1937), vol. 49, no. 2, pp. 254–258.

Blast Furnaces. All-Welded Blast Furnace Stove Operated at English Plant, H. M. Henderson. Steel (July 12, 1937), vol. 101, no. 2, pp. 65 and 67. Stove shell of 20-ft. diam. and 99 ft. high constructed of $^5/_8$- and $^7/_{16}$-in. thick plates; lap welded; erection and welding described.

Cars, Passenger. Welded Steel in High-Speed Railroad Service, E. Chapman. Mech. Eng. (June 1937), vol. 59, no. 6, pp. 409–412. Uniform stress distribution must be attained; undiscovered cracks are a great hazard of manufacture; far reachinge ffects of thermal expansion and contraction; two dimensional effects of thermal stresses. Before Am. Soc. Mech. Engrs.

Castings. Detecting Faults in Castings and Welds. Mech. World (July 9, 1937), vol. 102, no. 2636, pp. 27 and 30. While X-rays give positive indication of existence of flaws, there are other methods which, while not so positive, can give good results under suitable conditions; three of these, two electrical methods, and one employing sound waves, are described.

Crankshafts. Chrome-Vanadium Crankshaft Repair, J. Ryan. Industry & Welding (May 1937), vol. 10, no. 5, pp. 30–31.

Electric Welding, Arc. Arc Welding in 1936. Welding Industry (Feb. 1937), vol. 5, no. 1, pp. 12–14. Various achievements obtained in electric arc welding industry during 1936.

Electric Welding, Arc. Inspection of Welding, N. Dobson. Sheet Metal Industries (June 1937), vol. 11, no. 122, pp. 565–570.

Electric Welding Machines. Interrupted Spot Welding Uses Electron Tube Control, R. S. Pelton. Metal Progress (July 1937), vol. 32, no. 1, pp. 59–62.

Electric Welding Machines. British Industries Fair. Welding Industry (Feb. 1937), vol. 5, no. 1, pp. 15–20.

Electric Welding Machines. Arc Welding Rectifier. Engineer (Mar. 26, 1937), vol. 163, no. 4237, p. 362.

Electric Welding, Resistance. Application of Electric Resistance Welding to Non-Ferrous Metals. Machy (Lond.), vol. 50, no. 1285 (May 27, 1937), pp. 257–259. Spot welding and pressure welding operations discussed; difficulties experienced with aluminum and magnesium; welding machines.

Electric Welding, Resistance. Methods Used in Making Invisible Spot Welds, H. W. Roth. Steel (July 12, 1937), vol. 101, no. 2, pp. 44–48.

Floors. All-Welded Intermediate Floor for Heavy Workshop Load. Engineering (Apr. 2, 1937), vol. 143, no. 3716, pp. 369–370 and 378.

Motor Truck Manufacture. Flexible Welder Facilitates Truck Fabrication. Iron Age (May 20, 1937), vol. 139, no. 20, pp. 45–47.

Oxyacetylene Welding. New Oxyacetylene Butt Welding, C. G. Bainbridge. Welding Industry (Feb. 1937), vol. 5, no. 1, pp. 8–11.

Oxyacetylene Welding. Technical Aspects of Oxyacetylene Welding. Engineer (Apr. 2, 1937), vol. 163, no. 4238, p. 395.

Oxyacetylene Welding. Oxwelding Stainless Steel. Sheet Metal Worker (May 1937), vol. 28, no. 5, pp. 39–41.

Petroleum Cracking Plants. Steel for Pressure Vessels in Hydrogenation Plant, C. Berthelot. Metallurgist (Supp. to Engineer) (Apr. 30, 1937), pp. 22–23.

Pipe Lines. X-Ray Inspection of Field Welded Pressure Piping, H. R. Isenburger. Heating, Piping & Air Conditioning (June 1937), vol. 9, no. 6, p. 369.

Pipe, Steel. Welded Pipe Work and Specials. Welding Industry (Feb. 1937), vol. 5, no. 1, pp. 3–7 and 11. Discussion of methods and parts as manufactured by welding at British and Clyde Works of Stewarts and Lloyds, Ltd.

Railroad Maintenance of Way. Permanent Way Welding. Ry. Gaz. (Int. Ry. Congress Supp.) (May 21, 1937), pp. 17–18.

Railroad Tracks. Report of Committee V—Track. Am. Ry. Eng. Assn.—Bul. (Jan. 1937), vol. 38, no. 393, pp. 475–512, supp. sheets. Design of railbound frog castings; fastenings for continuous welding of rail; Welding Rails Together in Track, F. R. Layng; plans for switches, frogs, crossings, slip switches, etc., and track construction in paved streets; plates for RE rail sections; limiting relative positions of abutting rails of fixed and drawspans of bridges and proper tolerances; revised designs for cut track spikes.

Railroad Tracks. Welding Special Trackwork—How Burlington Does It, S. E. Tracy. Ry. Eng. & Maintenance (Aug. 1937), vol. 33, no. 8, pp. 543–545.

Shipbuilding. Electric Welding Installation and Organization in Shipyards, W. L. Faerman. Engineer (Apr. 9, 1937), vol. 163, no. 4239, pp. 428–431.

Shipbuilding. Cargo Capacity Increased by Welding. Shipbldg. & Shipg. Rec. (June 10, 1937), vol. 49, no. 23, pp. 717–720.

Steel Plates. Determination of Residual Strains and Stresses in Arc-Welded Plates, H. E. L. Martin. North East Coast Instn. Engrs. & Shipbldrs.—Tran. (May–June 1937), vol. 53, pt. 7, pp. 255–281, supp. sheets.

Steels for Welding, A. E. Gibson. Can. Chem. & Met. (May 1937), vol. 21, no. 5, p. 192.

Sugar Factories. Welding and Hard-Facing in Factory Maintenance. Facts About Sugar. (May 1937), vol. 32, no. 5, pp. 174–177.

Trailers Fabricated by Advanced Method. Automotive Industries (Aug. 7, 1937), vol. 77, no. 6, p. 188.

Tubes. Flexible Tubing from Strip. Iron Age (May 13, 1937), vol. 139, no. 19, pp. 60–61. Method developed by Chicago Tubing and Braiding Co., Maywood, Ill. of producing flexible tubing from monel, bronze or steel strip by means of autogenous welding.

Tugboats. Diesel Tug "Calacto," S. W. Richards. Mar. News (July 1937), vol. 24, no. 2, pp. 64–65. All welded steel tug built by Ira S. Bushey & Sons, Brooklyn, in 1936; length 77 ft.; beam 20 ft.; depth 11 ft.; propelled by Fairbanks-Morse 6-cyl., 400-hp. Model 35-E-14 starboard marine Diesel engine operating at 275 rpm.

Welded Steel Structures. Shall It be Welded? If So—How Designed? E. J. Charlton. Product Eng. (July 1937), vol. 8, no. 7, pp. 258–261 and (Aug.), no. 8, pp. 310–312. Some fundamentals that must be considered in selection of material and type of construction; some criteria for properly engineered welded structures; flame cut and formed parts discussed; some economic factors set forth.

Index to Advertisers

THE WELDING JOURNAL

Readers are urged to study the Advertising Section for latest advances in welding apparatus and supplies.

Air Reduction Sales Company . . Outside back cover
American Brass Company 55
American Telephone & Telegraph Company . . 53
Anti-Borax Compound Company 57
Bastian-Blessing Company 57
Chicago Hardware Foundry Company 57
Duraweld Metal Products Corp. 52
Foote Mineral Company 57
General Electric Company . . . Inside front cover
Handy and Harman 63
Harnischfeger Corporation 56
International Acetylene Assoc. 62
Martin P. Korn 52
Lincoln Electric Company . . . Inside back cover
The Linde Air Products Company 2
P. R. Mallory & Co. Inc. 56
Membership 60
Metal & Thermit Corporation 64
Metal Congress Exposition 58
National Carbide Corporation 59
Traymore Hotel 54
United States Steel 56
Victor Equipment Company 61
Weldit Acetylene Company 59

WELDING SOCIETY ACTIVITIES
AND RELATED EVENTS

August 23, 1937

To the Members of the American Welding Society

One of the most important accomplishments of the Society this year is the new Welding Symbols of the Nomenclature, Definitions and Symbols Committee. Those of us who are engineers and fabricators of welded equipment know the need of a definite system of designating welds on drawings. It is probably safe to say that today not 20% of the drawings made clearly specify the size and type of weld to be made. Far too many drawings simply state "Weld." There is as much excuse for this procedure as noting on a riveted structure "Rivet" with no further instruction regarding the size of rivets, the number required or the spacing, or detailing a casting without indicating the various metal sections. To expect the shop to guess the size and amount of welding to be done is manifestly unfair to the shop. Either too little welding will be done and the job fail, or too much welding will be done and the cost will be out of proportion. The welding operator or foreman is not a designing engineer. Generally he has not the slightest conception of the stresses to be encountered in operation. To ask him to accept the responsibility for design is certainly not good management.

The June issue of the Journal carries a nine-page description of these new symbols. They are the result of many years experience of the leading industrial companies and the best welding brains in America. On this committee were representatives of the American Standards Association, to which these symbols have been recommended. It seems safe to predict that the American Standards Association will adopt them.

The more wide spread these symbols are adopted, the sooner will much of the guess work be taken out of welding fabrication, the sooner will responsibility for welded joint strengths be placed squarely where it belongs—on the shoulders of the engineer. With their wide acceptance, purchasers will be protected, cost reduced and competition placed on an even basis. It costs much more than twice as much to lay a $^3/_4$" fillet weld than a $^3/_8$" fillet weld. If the larger weld is required, the shop should have that information. If the smaller weld has sufficient strength, it is uneconomical to make the larger one. I can see no reason for a continuation of the old haphazard method, except mental laziness and the lack of interest in proper construction. The future of welding demands that welding be safe and economical. Copies of the welding symbols may be obtained for twenty-five cents a copy from the AMERICAN WELDING SOCIETY Headquarters, 33 West 39th St., New York City.

In less than five weeks from the publication of the September Journal, our Annual Meeting will be held at Atlantic City. This year's meeting promises to be the largest and best one in the Society's history. There is a splendid technical program arranged and the exposition will outdo those of previous years. Any one interested in welding can make no better investment than to attend the meeting. It is not too soon to start talking to the boss about your making the trip.

This week I am attending a meeting of the Management Committee in New York. On September 10th will be held a meeting of the Board of Directors and Executive Committee. These will probably be my last Committee and Board Meetings as President of the Society. I have thoroughly enjoyed the associations, but I won't go into that now; I'll tell you more about that in next month's issue.

Don't forget that new member! This is important if we are to grow and expand our activities. Can't you get him signed up before October?

Yours sincerely,
A. E. Gibson, *President*

National Safety Council

Copies of the National Safety Council's Kansas City Congress program (October 11–15) may be obtained by members of our Society, who are interested in accident prevention.

There are altogether 125 separate meetings, a very important safety exhibit, many demonstrations and other features.

Any member of the A. W. S. will be cordially welcome and will be accorded all the privileges of the Congress.

Last year 111,000 people were killed by accidents—the cost was estimated to be $3,700,000,000. These losses can be cut down by acquaintance with the tried and tested safety procedures which will be discussed at this Congress.

Larger Hard-Facing Booklet

A new and more complete edition of the booklet, "Hard-Facing with Haynes Stellite Products," is now being issued by Haynes Stellite Company, Kokomo, Indiana, a unit of Union Carbide and Carbon Corporation. This booklet describes well over 500 money-saving applications of the hard-facing process.

This new edition is the fourth printing since the booklet was originally published a little more than three years ago. Over 35,000 copies have already been distributed. New sections present information concerning special Haynes Stellite J-Metal cutting tools and the corrosion-resistant Hastelloy alloys. A number of examples of hard-facing automotive and aircraft valves and valve seat inserts, and the use of Haynes Stellite trim for high-temperature, high-pressure steam valves, are now also described in detail.

Copies are available without obligation from Haynes Stellite Company, Kokomo, Indiana.

Introduction to Ferromagnetism

Book by Francis Bitter, Associate Professor of the Physics of Metals at the Massachusetts Institute of Technology. Defines as clearly as possible the problems whose solution may be expected to reveal the fundamental processes which constitute ferromagnetism, paves the way for a consideration of the subject from the point of view of solid solutions (impure materials) rather than perfectly homogeneous pure substances, and serves as an introduction and guide to the enormous literature on the experimental side of the subject. Published by McGraw-Hill Book Company. Price $4.00—314 pages.

Society Emblem

The AMERICAN WELDING SOCIETY has issued an attractive emblem which is available in the form of a pin. The following prices will prevail:

Gold-Plated emblem—screw back attachment—50¢
Gold-Plated emblem—safety lock catch attachment—55¢
8K Gold Emblem—screw back attachment—$2.50
8K Gold Emblem—safety lock catch attachment—$2.55

July Welding Journal

Members of the Society who can spare their July issue are requested to send these to the Secretary of the Society. A refund of 50¢ will be made for each copy received.

The supply of this issue has been exhausted and it is necessary to secure some additional copies.

Steel Convention

Over 5000 steel mill engineers and executives are expected to attend the Thirty-third Annual Convention and Iron and Steel Exposition, which will be held in the Stevens Hotel, Chicago, Illinois, September 28th, 29th, 30th and October 1st. This annual meeting of the Association of Iron and Steel Engineers is expected to be one of the largest in the Society's history, in view of the prominent position the steel industry maintains in the Chicago area. Approximately twenty-five papers dealing with actual operating problems in the industry will be presented by technical authorities. Along with the technical program, one hundred and fifty manufacturers of steel mill equipment will display their various products in the Iron and Steel Exposition. Many of these exhibits will be in actual operation. Two of the outstanding features of this meeting will be inspection trips to the Gary Sheet and Tin Division of the Carnegie-Illinois Steel Corporation, and the Indiana Harbor Works of the Inland Steel Company.

Pipe Lines

Latest information on the construction of pipe lines by electric welding for transportation of oil, gas and water is contained in a new bulletin just published by The Lincoln Electric Company, Cleveland, Ohio.

Foundrymen's Convention

The Board of Directors of the American Foundrymen's Association, meeting in Chicago, July 20th, accepted the invitation of the Northeastern Ohio Chapter and the city of Cleveland to hold its next convention and exhibition in Cleveland, May 14, 16, 17, 18 and 19, 1938. The last previous convention and exhibition of the American Foundrymen's Association held in Cleveland was in 1930.

The exhibition which will occupy the splendid facilities of the public auditorium and Lakeside exhibition hall will be set up and opened for the benefit of local and neighboring foundrymen on Saturday, May 14th. The technical sessions held in the spacious meeting rooms of the public auditorium group of buildings will start Monday morning and conclude with the closing of the exhibition Thursday, May 19th.

The central location of the convention city, the prominence of Cleveland as a castings center, with 118 foundries, making a wide diversity of all classes of castings, provides unusual facilities for plant visitation. The region of the lower great lakes is the metal working center of the United States and Cleveland is the focal point of production and use of castings.

Flame Hardening

A paper on Flame Hardening is being scheduled by the American Society for Metals on Wednesday, October 20th, in the Afternoon. Insamuch as there are no definite technical sessions scheduled by the Society on that afternoon, this will provide an opportunity for those interested in the paper to attend this session which will be held at the Convention Hall.

Qualification of Welders

A round table discussion by experts interested in the various phases of qualification of welders is being planned during the Atlantic City Convention. Those interested in this subject should indicate their desire to receive an invitation to this conference. Inquiries should be addressed to the Secretary of the Society.

For Football Fans

Knowing a number of members attending the Atlantic City Convention will hate to miss their regular Saturday games the following list of convenient games to Atlantic City may enable them to catch a good game enroute to and from the Convention.

Sat. Oct. 16th—Columbia vs. Pennsylvania. 2 P.M., Baker Field, New York City.
N. Y. U. vs. St. Johns College. Ohio Field, New York City.
Navy vs. Harvard. Stadium, Baltimore, Md.

Fri. Oct. 22nd—Carnegie Tech vs. Temple. 8:30 P.M. Temple Stadium, Phila.

Sat. Oct. 23rd—Princeton vs. Rutgers. Princeton, N. J.
Pennsylvania vs. Georgetown. Franklin Field, Philadelphia.
Maryland vs. Syracuse Baltimore, Md.

Lincoln Gold Medal

The Lincoln Gold Metal, offered by Mr. J. F. Lincoln, president of The Lincoln Electric Company, Cleveland, Ohio, as a stimulus to the preparation of worth while contributions to the art of welding, is pictured in the accompanying illustration. The metal is $2^1/_2$ inches in diameter and is to be of solid gold. One side of the metal will bear the wording, "Lincoln Gold Metal Award—AMERICAN WELDING SOCIETY." This inscription will surround a central figure symbolic of electric welding. The figure will be of an arc welding operator with the arc in operation. The wording on the reverse side of the medal will be in relief. Also, lettered in relief on the reverse side will be the name of the individual winning the award, together with the date of presentation.

There are no restrictions as to subject matter of papers eligible to compete for the award. The paper may be on the

electric arc process, gas welding, resistance welding or any other form of welding within the scope of the AMERICAN WELDING SOCIETY. The paper may be one read before any sectional meeting of the Society or at the general fall meeting. It must, however, be published in the Journal of the Society between November 1936 and October 1937. The decision as to the best paper will rest with a committee of the Society selected by the President. This committee consists of Col. G. F. Jenks, Chairman, K. V. King and F. E. Rogers. The medal will be presented during the annual convention of the AMERICAN WELDING SOCIETY in October.

Advantages of Steel Building Welding

Reprinted from Aug. 1, 1937 issue, *New York Times*

One of the clauses in the new building code which met with considerable objection during the discussions on the code changes in the Board of Aldermen was that permitting welding instead of riveting in steel construction. The new code, which was signed last week by Mayor La Guardia and will go into effect Jan. 1st, next, permits the use of welding under strict regulations.

Gilbert D. Fish, structural engineer and a member of the committee on bridge welding of the AMERICAN WELDING SOCIETY, 33 West Thirty-ninth Street, points out that in spite of the prohibition which has formerly prevailed against the use of welding in New York City, there is at the present time one large welded building within the city limits. That is the recently completed addition to the Brooklyn State Hospital, which cost approximately $1,000,000.

As the building was erected under the supervision of the State Department of Public Works, headed by Colonel Frederick Stuart Greene, it was not subject, points out Mr. Fish, to the city's regulations. The structure, which consists of two large wings, each 40 by 175 feet, is six stories in height but has been planned so that three extra stories may be added when needed in the future. About 600 tons of steel material were used in construction and the building was welded throughout. One reason why that method was adopted was that it would eliminate disturbing noises for the patients. Mr. Fish also states that the welding process

caused a saving of about sixty tons of steel.

Welding is also being used for the two caissons for the Long Island tower of the Bronx-Whitestone Bridge, now under construction. The caissons are huge steel boxes, considerably over 100 feet high, which will be filled with concrete and sunk through the sand to bed rock. The caissons are constructed in sections. After the bottom section is floated to the site, the next section will be welded to it, and this process will be continued as sinking takes place until the entire caisson is completed.

Sees Building Progress

"Permission to use welding, as authorized in the new code," states Mr. Fish, removes the last serious obstacle to the general use of welding in building construction. Elsewhere throughout the United States and in all foreign countries the welding of buildings has been permitted either by specific code provisions or by special authorization.

"As the new city code is the result of several years of hard work by many able architects, engineers and other specialists in the building field, it will doubtless serve as a model for other cities where codes have become antiquated. Hence, New York's approval of welded buildings may be considered the last word in the discussion of this new engineering technique, which began seventeen years ago.

"Welding takes the place of riveting. In a welded building, the various members of the steel framework are connected by fusing them together with high heat. This heat can be obtained from either the oxyacetylene torch or the electric arc, but in practically all construction work the welding is done electrically.

Advantages Pointed Out

"From the standpoint of the public, the most interesting feature of welding for building construction is its noiselessness. The rattle of the pneumatic riveter, which interrupts conversations and racks the nerves of those in the immediate vicinity is eliminated.

"From the standpoint of the engineer, the chief advantages of welding are that it makes possible lighter, stiffer and more compact joints, and often effects a considerable saving in the amount of steel required.

"A welded joint can always be made as strong as the steel work if there is any reason for so doing. In other words, with welding, full advantage can be taken of the strength of steel. Stiffness is of special importance in tall buildings that require heavy wind bracing. A welded tower will sway less in a gale than will a riveted tower. Welding is also preferred in the construction of buildings braced against earthquakes.

"There is a considerable saving in the amount of steel required when welding is employed, because the design of the steel members can be simplified. This saving runs from 4 to 10 per cent of the total steel structure and may run as high as 25 per cent for certain forms of trusses and plate girders.

Work Often Simplified

"Frequently, welding simplifies the work of the architect by eliminating protruding brackets and other unsightly elements. Welding also simplifies the fabrication of the steel, as there is very little puching of holes. This in itself saves money and also permits quicker delivery.

"In repairs, alterations and rebuilding operations, where welding has been used, new steel can be installed without drilling holes in the old steel or making exact measurements. When the War Department decided to stiffen the head and upraised arm of the Statue of Liberty in order to decrease swaying in the wind, welding was employed. This simplified an otherwise very awkward job and eliminated the noise which would have been caused by riveters working inside the metal structure.

Notable Welded Buildings

Mr. Fish explains that at the present time there are more than 200 welded buildings in the United States. Among them are nine buildings at Yale University, the sports building and library at Vassar College, the chemistry building at Trinity College, the Greenwich (Conn.) High School, the Kent School buildings at Kent, Conn.; the Nathan Hale School at Mount Vernon, N. Y.; the Edison Company's fifteen-story office building in Boston, the nineteen-story office building of the Dallas Power and Light Company, Texas; an eleven-story laboratory building in East Pittsburgh, several factories in Bridgeport and the five-story factory of the Westinghouse Electric and Manufacturing Company at Sharon, Pa., erected in 1926, and which, says Mr. Fish, was the world's first large welded building.

Among the notable foreign structures which have utilized the welding system is the large addition recently completed for the Bank of England in London, in which about 4000 tons of steel were used.

The Austin Company, engineers and builders of this city, announces that two welded buildings are now being constructed by that firm, one in Meriden, Conn., for the International Silver Company and the other at LaGrange, Ill., for the Electro Motive Corporation.

"The rigid frame type employed in welding the Meriden building," said J. K. Gannett, Vice-President of the Austin Company, "serves to demonstrate the trim appearance attained in factory buildings under methods of construction which until now have been outside the law. Aisles up to fifty feet in width, entirely without obstruction from floor to roof, can be provided in plants of this type, from which all the objectionable shadows caused by trusses or other cross members are eliminated. Working conditions are thus greatly improved."

Structural Welding

How Far Have We Gone in This Field?

Editorial Reprinted from July 1937 issue, *Railway Engineering and Maintenance*

Ten years have come and gone since fusion welding was first applied on a comprehensive scale in the strengthening of a steel railway bridge, the Chicago Great Western crossing of the Missouri River at Leavenworth, Kan. What progress has been made in the extension of welding to railway structures during this decade?

The work on the Leavenworth bridge was heralded as the dawn of a new era in steel bridge building and within a year the construction of an all-welded steel truss span for a spur track on the Boston & Maine at Chicopee Falls, Mass., was the object of widespread publicity on the part of the proponents of the new process. However, this latter project proved of greatest value in demonstrating that there was much to learn about the application of welding to the construction of steel bridges before it could supplant riveting in the fabrication and erection of new bridges, and only a few welded railway bridges have since been constructed.

The reasons are not hard to find. Railway bridge engineers are conservative; they realize that the enviable record for freedom from bridge disasters represents the result of years of development, that embraces everything from a superior knowledge of the mathematics of bridge design to better trained and more effectively organized maintenance forces. They know also that design practice today is better than it was in the past, not only because of a better knowledge of the theory of structures and the properties of materials but also because it is based on accumulated field experience with the behavior of riveted joints in all manner of details and under a great variety of conditions. Such a knowledge, they contend, cannot be reproduced overnight regarding an entirely new method of connecting steel plates and shapes.

In the meantime, however, railway bridge engineers and their field forces have applied fusion welding on an extended scale to the repair and strengthening of old bridges, the results of this work have been carefully studied, and practices revised as faulty results indicated the need for changes. Furthermore, railway engineers have cooperated with others who are vitally interested in this process in endeavoring to find the answers to some of the perplexing problems involved—for example, the question of locked-up stresses resulting from the heating of the base metal, and the strength of welds—especially the fatigue strength to resist stress reversals. In carrying on this work they participated in the drafting of the first comprehensive specifications of structural welding, and under the auspices of the American Railway Engineering Association they have drafted a set of specific recommendations covering work in this field. This treatise should prove of such value both in the office and the field that it is presented in abstract elsewhere in this issue.

Thus it is seen that, while progress has been slow, it has been conducted in an orderly fashion that has been fruitful of results which should lead to a steady increase in the application of the fusion welding process in railway bridges.

LINCOLN FOUNDATION

By A. F. DAVIS†

Can you imagine that a manufacture, constructor or any one who utilizes steel construction would continue in their present way or methods, if they really and truly believed they could save from 10 to 50% of their cost by using arc-welded construction? They just couldn't go on with their present method. They would find ways to overcome the fact that their engineer did not know how to design for arc welding, that their salesmen did not like the appearance, and the hundreds of arguments and excuses that are put forward for not using arc-welded construction.

Now, if the general manager of a company would really make a study of the way his machine products are designed, go through it from A to Z, find out for himself the facts about arc welding, wouldn't he believe it? I think he would. If an engineer with a manufacturing or construction company should make a thorough study of the design of the machines or of the construction which they are using and apply arc welding or arc-welded steel to its construction and then present these facts to its management, don't you believe that the management would believe what he says? I think they would. This would mean, therefore, that they would adopt arc welding and arc-welded construction as rapidly as possible.

The object of the Foundation's work is to do just this. To get the men at the head of companies to make a study of their products or methods of construction and find out the facts for themselves or to appoint one or more people in their organization to make a study of arc welding as applied to their own construction. Get this in the form of a report and submit it to the Foundation as a paper. Or to get some, engineer or designer, production man, etc. on his own initiative, to make a study of the machinery or constructions which his company uses. Prepare it in the form of a report and submit it as a paper. We believe that the management will believe reports prepared in this way and if they do they must go to arc-welded construction.

†Secretary, The James F. Lincoln Arc Welding Foundation.

Obituary

MAJOR R. A. BULL

The AMERICAN WELDING SOCIETY learned with great regret of the sudden and unexpected death of Major R. A. Bull who passed away on July 9, 1937.

Many of the members of the Society will recall that Mr. Bull has been instrumental in bringing the foundry and the welding industry together. Time and again, he urged each industry to appreciate the value and benefits of the other. Largely through his efforts the promotional work of the Society has been along the lines of the use of welding to supplement and aid castings. In other words, Mr. Bull recommended that castings be used in conjunction with welding where each was economical.

MARTON P. KORN
CONSULTING WELDING ENGINEER
Ellicott Square Buffalo, N. Y.

EMPLOYMENT SERVICE BULLETIN

SERVICES AVAILABLE

A-240. Graduate Metallurgical Engineer 32, with 10 years' practical and theoretical experience in metallurgy, 4 years' practice in the manufacturing and testing of welding wire, also with experience in surfacing and flame hardening, now employed by big steel concern wants to get in contact with welding wire manufacturer interested in the development of a novel welding wire product.

SECTION ACTIVITIES

CLEVELAND

Chairman E. R. Benedict of the Cleveland Section has been appointed as representative of this Section on the National Board of Directors.

NORTHWEST

Formal Organization meeting of the Northwest Section was held at the Minnesota Union, University of Minnesota, Wednesday, July 28, 1937 at 6:30 P.M. The Chairman advised those present that the application to authorize the organization of the Northwest Section had been approved by the AMERICAN WELDING SOCIETY. Nominees for officers and members of the Executive Committee as recommended by the Nominating Committee were duly elected to serve until the first annual meeting in May 1938. The names and connections of the nominees so elected are as follows:

Chairman: Harry J. Kicherer, American Hoist & Derrick Co., St. Paul.

Vice-Chairman: C. M. Akins, Marquette Manufacturing Co., Minneapolis.

Secretary-Treasurer: Alexis Caswell, Manufacturers' Association of Minneapolis, Inc.

Executive Committee: J. H. Barron, Brown Sheet Iron & Steel Co., St. Paul; C. E. Comfort, St. Paul Structural Steel Co., St. Paul; G. W. Irwin, Air Reduction Sales Co., Minneapolis; Fred Klass, General Electric Co., Minneapolis; H. A. Lindeke, Nicols, Dean & Gregg, St. Paul; William E. Murphy, Northern States Power Co., Minneapolis; John Nelson, Butler Manufacturing Co., Minneapolis; R. H. Newton, Lincoln Electric Co., Minneapolis; R. W. Robinson, American Bridge Co., Minneapolis; V. L. Sage, Commercial Gas Co., Minneapolis; G. V. Watson, Flour City Oxwelding Co., Minneapolis; J. E. Williams, Linde Air Products Co., Minneapolis.

Representative on National Board of Directors—Harry J. Kicherer.

Mr. L. A. Dills, Senior Engineer, State of Minnesota Department of Highways, gave a most interesting presentation of "Welders' Qualifications."

SAN FRANCISCO

The San Francisco Section held the first meeting of the year 1937–1938 at the Engineers' Club on August 20th. Membership plans were announced. This Section also plans to give a prize for the best paper written by students of the various universities within a certain district to be decided upon by a committee of the Section.

Mr. K. V. King presented a brief review of the various articles published in recent issues of the Journal.

Mr. L. W. Delhi, General Manager of the Western Pipe and Steel Company of San Francisco, addressed the audience on "Organization Work in Connection with Fabrication of Large Welded Pipe Line Contract."

UNCOATED HARD SURFACING RODS
Electric arc or oxy-acetylene welding

DURAWELD NO. 1—for gear teeth, cam races, valve seats, etc., needing filing and machining after application.

DURAWELD NO. 2—for road and grading machines, bulldozer shoes, rail joints and other excessive wearing parts. A self hardening rod. Stays hard under heat.

DURAWELD NO. 3 or 4—for lathe center plugs and tipping concrete and stone drills. When ground, rods will drill through spring steel.

Bushings or similar hard wearing parts can be cast to order.

DURAWELD flows like bronze, binds with any ferrous metal, fuses at low temperature; SAVES 10% to 15% IN GAS, TIME AND LABOR.

Send for samples and details.
Distributors wanted. Reorders assured.

DURAWELD METAL PRODUCTS CORP.
41-08 24th Street, Long Island City